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RELATION OF GLUME STRENGTH AND OTHER CHARACTERS TO SHATTERING IN WHEAT[1]

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A TEST for glume strength devised as an aid in selecting new shatter-resistant wheats has been employed with some success at Pullman, Washington. The method was first tested to determine if strong outer glumes, as measured by the resistance to a side pull, were associated with resistance to shattering. Shattering resistance, however, as is shown later, depends not alone upon glume strength but also upon other characters, such as length, shape, and position of floral parts, type of head, and erectness and height of plant.

Data on the strength of the outer glume of eight representative varieties of wheat and on the relationship of glume strength and other characters to shattering are presented here.

MATERIAL AND METHODS

The eight varieties of wheat selected for the glume-strength studies because of their range in shattering tendency and their shattering ratings as determined by observation in the field are listed below:

Variety	C. I. No.[3]	Shattering Rating
White Odessa	4655	Highly resistant
Rex M1	11689	Highly resistant
Kharkof	1442	Resistant
Ridit	6703	Resistant

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the Farm Crops Section of the Agronomy Division of the Washington Agricultural Experiment Station, Pullman, Wash. Most of the data are from a thesis submitted to the State College of Washington in partial fulfillment of the requirements for the degree of doctor of philosophy. Scientific Paper No. 466, College of Agriculture and Experiment Station, State College of Washington. Received for publication February 17, 1941.

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[3]C. I. refers to accession number of the Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture.

Golden	10063	Moderately susceptible
Mosida	6688	Susceptible
Fortyfold	6176	Susceptible
White Odessa	4651	Susceptible

Varieties classed as "resistant" showed only a trace of shattering after mild winds during a period of low relative humidity. Mature heads of the eight varieties, illustrated in Fig. 1, were gathered at random from the varietal nursery and field plats at Pullman, Wash., in 1937. They were harvested before winds of sufficient strength to cause damage had occurred.

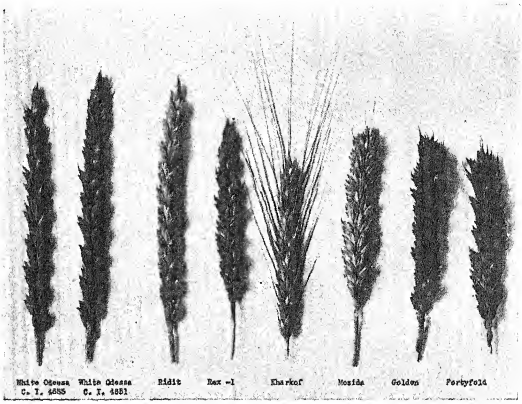

FIG. 1.—Heads of eight varieties of wheat used in glume-strength studies.

The strength of a glume, as recorded in this paper, is the number of grams of a perpendicular outward pull, 7 mm above its base, required to break the outer glume from the rachis. Glumes which were less than 7 mm long were pulled from a distance of 6 mm, but the strengths recorded were calculated to a 7-mm leverage. The determinations were made by a specially-made spring balance, equipped with a dog to hold the indicator at the reading at which the glume broke. Recently, however, a more simple and efficient pocket-size scale has been built (Fig. 2). Since it gives substantially the same readings as the older balance and will be used in all subsequent determinations of glume strength, the new instrument only is described here.

The spring arm of this scale was made from a 5-inch piece of No. 16 steel piano wire. A loop near the attached end of the wire permits the free end to operate in an arc having a radius of approximately 3½ inches. The tip ⅛ inch of the free end of the spring arm was bent downward and flattened to form a hook that could be inserted down between the glume and lemma without affecting their position

materially. The tip of the hook was bent slightly to the left and sharpened so that it would become attached to the glume sufficiently to prevent slipping. A short piece of shipping tag wire attached to the spring arm with its free end 7 mm below the tip of the hook served as a guide to insure that the tip of the hook would be placed exactly 7 mm above the base of the glume.

As a glume is pulled away, the spring arm moves along the scale until the glume breaks off. Then the spring arm flies back leaving the small indicator rider at the farthest point reached by the spring arm. The strength of the glume is indicated on a previously calibrated graduated scale. The rider slides back to the zero position when the scale is tilted to the left. Further details regarding either of the two instruments will be furnished upon request.

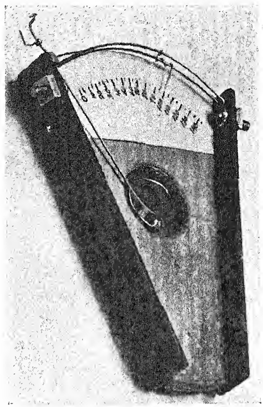

FIG. 2.—A pocket-size scale for measuring glume strength.

In recording the data on glume strength the spikelets in a head were numbered from the uppermost or tip spikelet downward to the lowest one containing a fertile floret.

Within a spikelet the outer glume adjacent to the lower or first floret was designated as the first glume, and that adjacent to the second floret as the second glume.

The strength of the two glumes was recorded separately. Comparisons between varieties were based upon the average strength of the first and second glumes of corresponding spikelets of 30 heads. Records from basal spikelets of the larger heads were excluded because the corresponding numbered spikelets were absent from many of the heads.

EXPERIMENTAL RESULTS

GLUME STRENGTH AND SHATTERING

An examination of the graphs in Fig. 3 which show the glume strength indicates that the varieties rank from the greatest to least strength approximately in the following order: White Odessa (C. I. 4655), Ridit, Rex M1, Kharkof, White Odessa (C. I. 4651), Fortyfold, Mosida, and Golden. This order differs somewhat from the grouping for shattering shown above although the four varieties classed there as susceptible or partly susceptible to shattering had lower glume strengths than the four classed as resistant or highly resistant.

The graphs in Fig. 3 also show that the glumes in the second spikelet usually were the weakest and that the breaking strength of the glumes increased progressively from the second spikelet down the spike. The second of the glumes in the first or tip spikelets did not

conform to that of the remainder of the spike. In the first spikelet the first glume is relatively strong, whereas the second glume is often little or no stronger than the corresponding glume in the second spikelet. When data from the first and second spikelets are excluded, the second glumes show a greater breaking strength than the first glumes in six of the eight varieties and no difference in the other two varieties.

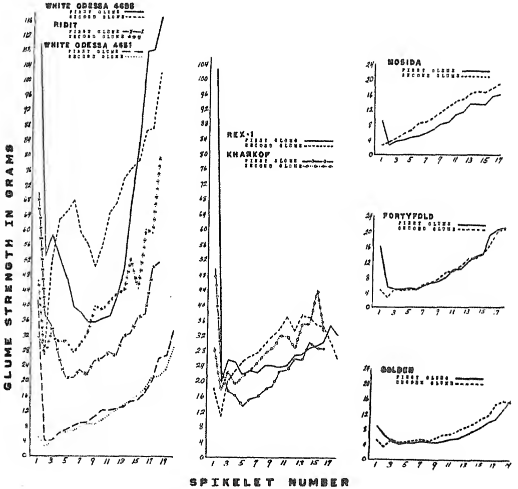

FIG. 3.—Average strength of the first and second glumes on the different spikelets of eight varieties of wheat. Spikelets numbered from the tip of the spike downward.

The percentage shattering in two nurseries of six of the eight varieties studied is shown in Table 1.

In general, these data support the ratings given above, although there are some discrepancies both as compared with the ratings referred to and as between the two nurseries. For example, Golden shattered 75% 24 days after maturity at Pullman in 1938, as compared with 50% for Mosida, whereas at Walla Walla in 1934 Mosida shattered 14% and Golden only 6%. Observations have suggested that Mosida begins to shatter more easily than Golden, but during very strong winds the latter variety loses more grain. The greater

shattering of Kharkof as compared with Ridit can be explained by a difference in glume strength as already noted.

TABLE 1.—*Percentage of shattering in six varieties of wheat at Pullman and Walla Walla, Wash.*

Variety	Pullman (1938)		Walla Walla (1934) at maturity
	At maturity	24 days after maturity	
Fortyfold	1	90	38
Golden	0	75	6
Mosida	Trace	50	14
Kharkof (checks)	0	5–25	1–9
Ridit	0	5	1
Rex Ml	0	1	0

In order to determine whether all parts of the head tend to shatter alike, from 66 to 186 heads each of Ridit, Golden, Fortyfold, and Mosida wheat which had lost at least one kernel during wind storms at Pullman in 1939 were examined. The average percentage of shattering for each spikelet of each variety is shown in Table 2.

TABLE 2.—*Percentages of first and second floret kernels missing from heads of Ridit, Mosida, Golden, and Fortyfold which had lost at least one kernel per head during wind storms at Pullman, Wash., in 1939.*

Spikelet No.	Variety and percentages of missing first and second floret kernels							
	Ridit		Mosida		Golden		Fortyfold	
	1st floret	2nd floret	1st floret	2nd floret	1st floret	2nd floret	1st floret	2nd floret
1	0	1	29	62	33	43	33	49
2	10	45	62	85	33	50	43	58
3	12	39	27	65	34	43	35	55
4	5	19	11	42	16	25	23	42
5	3	20	8	24	13	19	20	31
6	3	15	3	30	4	20	12	42
7	4	12	3	17	5	12	10	25
8	4	12	0	9	2	12	2	35
9	2	11	2	2	2	13	1	46
10	1	11	2	14	1	22	4	33
11	2	4	0	9	2	14	5	40
12	1	4	0	11	0	20	4	27
13	2	2	2	3	1	12	5	23
14	0	1	3	11	1	19	7	22
15	2	0	6	9	0	12	0	29
16	0	0	3	10	4	9	3	25
17	—	—	—	—	1	9	0	28
18	—	—	—	—	0	3	4	7
19	—	—	—	—	0	0	—	—
Average	3.2	12.3	10.1	25.2	8.0	18.8	11.7	34.3

The data clearly show that the second florets are more inclined to shatter than the first florets and that the upper spikelets tend to shatter much more than those toward the base of the spike. The second spikelet usually shattered the most with a progressive decrease downward. The tip spikelet, however, shattered considerably less than did the second spikelet. The shattering behavior within a spike corresponds closely with the trends in glume strength shown in Fig. 3, except that the second floret whose glumes generally were stronger than those of the first floret tended to shatter more. This may be due to the greater exposure of the second floret.

OTHER CHARACTERS AND SHATTERING

There are wide differences in morphological characters of the eight varieties of wheat studied, as is evident from the photograph in Fig. 1. It also is obvious from this and from the data in Fig. 3 and in Tables 1 and 2 that characters other than glume strength must affect shattering in wheat. Among these characters are position in the spike, which was described above, and in addition shape of spike, exposure of the floret, length of glume and awnlet, presence and type of awns, and position of the spike. Thus, in clavate spikes, the florets near the compact tips protect or brace one another against the shocks which cause shattering. The extreme clavateness of the spikes of Golden, for example, is one of the characters which causes this variety to shatter less than the stronger glumed Fortyfold variety.

Compactness in any part of the spike also offers protection from shattering as is evident in the lower part of the spikes of Golden where shattering is less in comparison with other varieties than the lower strength of the glumes would indicate.

Long glumes and awnlets result in a greater leverage to facilitate the breaking of the glumes and tend to increase the shattering. As a result Ridit shatters more than does Rex M1 (Table 1) despite its greater glume strength. The first spikelets of Ridit, however, shatter very little (Table 2) because the glumes are short as well as strong (Fig. 3). The longer awnlets in White Odessa (C. I. 4651), as compared with the other strain (C. I. 4655) of that variety, doubtless play a part in the greater shattering of the former strain. However, the chief cause of differences in shattering between the two strains of White Odessa is the greater glume strength of C. I. 4655.

Kharkof has weaker glumes and shatters more than does Ridit when the plants are erect. Kharkof, however, has a weak straw which often results in lodging before maturity or leaning or hanging down of the heads after maturity, where they are protected from the wind. Thus, when the heads of Kharkof are down, less shattering occurs than in Ridit, the plants of which are usually erect. The long, flexible, and spreading type of awn of Kharkof cushions the collisions between heads during wind storms, thereby reducing the shattering losses from that which could occur if such awns were absent.

In breeding wheats in which resistance to shattering is desired, attention should be given to the morphological characters described above which tend to limit shattering. Where feasible, selection in the breeding material should be deferred until after shattering is

evident. Tests of glume strength should be valuable after the strains become relatively uniform, particularly where conditions often do not favor natural shattering.

SUMMARY

A new device to measure glume strength is described and the relation of the strength of the outer glumes and of other characters to shattering was studied in eight varieties of wheat.

The outer glumes of the second spikelet from the tip of the head usually were weaker than those of any other spikelet. The strength of the outer glumes increased progressively down the spike. The glumes of the tip spikelets were stronger than those of the second and in some varieties were stronger than those of any other spikelet and shattered less.

Except in the tip floret, the second glume tended to be stronger than the first glume of a given spikelet in six of the eight varieties studied and approximately equal in the other two. The second floret, however, shattered more easily than the first in almost every spikelet, probably due to its greater exposure.

In addition to weak glumes, characters favoring shattering include long glumes, lemmas, and awnlets, and lax, non-clavate, erect spikes.

Awns of the Kharkof type, by cushioning the shocks of colliding heads, tend to reduce shattering losses over those which could occur if such awns were absent.

RELATIVE GROWTH RATE OF THE MAIN STEM OF THE COTTON PLANT AND ITS RELATIONSHIP TO YIELD[1]

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THERE is a great deal of speculation every year with regard to the probable yield of the cotton crop. Estimates of yields of cotton are based mainly upon the opinion of farmers, ginners, and others who are concerned directly with production of the crop. Physical factors, such as weather conditions, acreage, and stand of plants, also serve as a basis for estimates of cotton yields. These estimates might be improved upon if more were known about the behavior of the plant itself—how it grows and the relationship between the vegetative and fruiting parts. The purpose of this paper is to record some studies on cotton that have a bearing on this relationship and its possible use in estimating yield.

REVIEW OF LITERATURE

The growth structures of the cotton plant have been described by Cook and Meade (4)[3]. The fruiting areas are the main structures concerned in this study. The primary fruiting area of the cotton plant includes the fruiting limbs which extend horizontally from the central stalk or main stem. In some varieties secondary fruiting limbs are borne on vegetative branches which develop near the base of the main stem. The important feature about the primary fruiting limbs is that they are always initiated at the apical growing point of the main stem. There are two buds at the base of each cotton leaf, the true auxiliary bud which continues vegetative growth and the extra-auxiliary bud which produces the fruiting limb. The fruiting limb is first observed as a minute floral bud or "square" between stipules of the leaf on the main stem. The first internode of the fruiting limb lengthens, thus carrying the square and its leaf away from the main stem.

As the plant grows in height more fruiting limbs arise at given intervals of time. This is termed the vertical order of the fruiting limbs. In the same manner more floral buds arise as the fruiting limbs grow horizontally. This is termed the horizontal order of the floral buds. The mean intervals of time for both the vertical and horizontal orders are fairly constant throughout the entire fruiting period. Martin, Ballard, and Simpson (8) found the mean intervals of the vertical order to be 2.4 to 3.3 days and of the horizontal order 6.1 to 6.6 days. The time interval and internodal length between any two successive fruiting branches or floral buds may vary considerably with environmental conditions and varieties (5).

Investigators in other fields, such as plant physiology and animal nutrition, have studied the problem of growth rate from a physiological standpoint. Brody (3) and his co-workers at the Missouri Experiment Station in measuring growth of animals recognized cycles, or periods of growth rate, and found that a sigmoid

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[2]Associate Agronomist. The author is indebted to Dr. H. C. Fryer of Iowa State College and to Dr. R. R. Sullivan of Tennessee Agricultural Experiment Station for valuable suggestions; also to Dr. Charles F. Sarle of the U. S. Agricultural Marketing Service, Division of Agricultural Statistics, who furnished clerical assistance.

[3]Figures in parenthesis refer to "Literature Cited", p. 602.

or S curve represented these periods. With plants, these cycles might correspond to the following three periods: Early seedling, early blooming, setting and maturing fruits. Many plant investigators who have studied growth rates corroborated three phases of plant growth and described them by typical S curves. Pope (9) showed that the aerial plant structures grew with increasing rapidity until the fruiting structures destroyed the nutritional balance requisite for active growth of the vegetative growing point. Additional investigations are not only in agreement with Pope's work on barley, but they also show that the vegetative growing point is either retarded by fruits maturing on the plant or renewed by removing the fruits.

The disagreement seems to be in the choice of an equation which could be applied to these phases of growth. Brody (3) has made a critical analysis of most of these equations and has shown that a generalized equation cannot apply to all three phases. Blackman (2) probably was the first to formulate the compound-interest law of plant growth. His equation, $W_1 = W_0e^{rt}$, is identical with Brody's, $W = Ae^{kt}$. There is this difference in interpretation, however; whereas W_1 is the final dry weight in Blackman's equation, it is the weight at any point of time, t, in Brody's equation. In these equations, e is the Naperian base of natural logarithms and k is the instantaneous relative rate of growth for any given unit of time, t.

Also, in these equations, it is noted that weight, W, is used as the measure of growth. Reed (10) found that the apical growth rate in plants measured as height, H, could be used in place of weight expressed as dry matter. Heath (6) was probably the first to suggest extensive growth-rate measurements on cotton. His equation $H = Ae^{bt}$ is identical with Brody's equation. The interpretation is also very similar to Brody's. Evidently, Heath (6) did not intend for his equation to fit the entire period of growth rate, since he suggested that the measurements be taken only until the time of first open flowers.

Afzal and Iyer (1), following the suggestion of Heath (6), used the algebraic method of obtaining percentage growth-rate, which requires considerably more calculation than the very simple graphic method of Brody (3). Their results are used later in this paper for a comparison of their varieties with those in the present studies.

MATERIALS AND METHODS

The studies recorded in this paper were made at Knoxville, Tenn., over a period of 7 years, from 1931 to 1938. Although cotton is not grown extensively in the area around Knoxville, satisfactory yields have been obtained at the Experiment Station, and the plant grows normally without any infestation of the boll weevil (5). Varieties of the upland type, *Gossypium hirsutum*, were used. In determining the growth rate measurements on live plants, the height was taken at weekly intervals on plants selected at random.

A stake graduated with lines 1 inch apart was driven perpendicularly into the soil about 3 inches from each plant. In measuring height a carpenter's square was placed with one edge along the graduated face of the stake and the other edge tangent to the growing point of the apical bud. In 1931, 1932, and 1933 many measurements were taken after the cotton plants were dead. If care has been taken by the pickers and the leaves have shed, the skeletal framework of each plant and the nodes representing the floral buds can be readily observed. (For purposes of this discussion these nodes are termed "fruiting" nodes.) Thus, measurements of height and counts of bolls and fruiting nodes for correlation with the plant's actual performance, or yield, were taken after the plant was dead.

The data in Tables 1, 2, and 3 were obtained from field measurements taken at this time.

EXPERIMENTAL RESULTS

If it is assumed that yield is associated with rapidity of growth of live plants, then yield should show some association with final height of plants after they are mature or dead. The taller the plants, the more fruiting limbs will be initiated, and the environment causing increase in the vertical order should also cause lengthening in the horizontal order. Thus, the total number of fruiting nodes on the plant gives a relative index as to the maximum potential crop. Table 1 shows the association of final height with the number of fruiting nodes, or the potential crop. The correlation coefficient .6461 is beyond the 0.1% level and of high statistical significance. The mean $\bar{y}$ of 33 nodes per plant indicates that this number of bolls should have been obtained, when, as a matter of fact, only about 12 bolls per plant were picked. A high degree of shedding had occurred.

The question then arises, Is height still as closely associated with yield, when shedding is included? Table 2 shows the association of height with number of bolls, and again the correlation coefficient .4826 is beyond the 0.1% level and of high statistical significance. As may be noted in this table, data for 1931 were included, but this did not raise the correlation because a greater percentage of shedding took place in 1931 than in 1932 or 1933 (5).

Since the correlation coefficient between height of plant and number of bolls given in Table 2 was not lowered enough to affect significance, then shedding must have taken place largely in the horizontal order. The data of Table 3 show that this happened. The grouping of the data in Table 3 is illustrated by the diagram of fruiting areas on a cotton plant in Fig. 1. Zone A represents an area containing the first horizontal fruiting node positions immediately adjacent to the main stem, zone B the next area or second node positions, etc. Thus, from Table 3, 58.23% of the bolls in 1931 were produced in zone A on the first nodes, and in each of the 3 years from 70 to 85% of the bolls were found in zones A and B, containing first and second nodes. This, of course, is not an absolutely true picture of the shedding area, because there is less chance of producing limbs with six and seven fruiting nodes than with one and two. Then, too, a variety like Stoneville has an excess of vegetative branches on which there are secondary fruiting limbs. The fact remains, however, that the plant had to grow in height in order for the short limbs of No. 1 and 2 fruiting nodes to be formed.

It has been shown that growth measurements on plants of varied character indicate that there are three general periods of the growth process. The mean gains in height reported in Table 4 show that two of these periods may be easily designated with cotton. The growth rate of the cotton plant in the seedling stage is not so clearly shown because measurements in this stage can be more accurately taken by weight of dry matter. Furthermore, it was not considered desirable to begin measurements until June 10 when continuance of normal growth seemed assured. It may be noted in this table that the period

of most rapid growth during most years was from July 1 to August 5. After that time, rate of growth receded until September 9, at which time practically no growth occurred. No clear-cut lines can be drawn

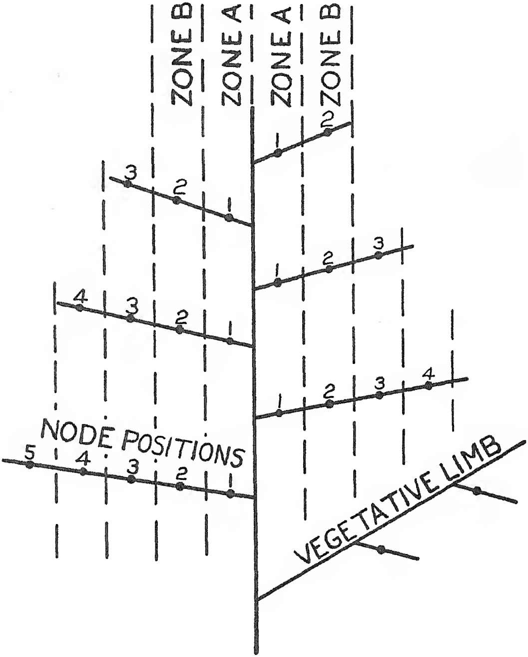

FIG. 1.—Diagram of cotton plant showing zone areas, node position on fruiting limbs, and vegetative limb.

with reference to the period of most rapid growth, but from Fig. 2 it appears to be closely associated with blooming. The maximum growth rate takes place about 3 weeks before the peak of blooming. Inmander, Singh, and Pande (7) stated that in their experiments the flowering period began at a definite interval, 27 to 35 days after the maximum growth. It is further noted in Table 4 that the growth

TABLE 1.—*Correlation of height of main stem of cotton plant with number of fruiting nodes, measurements taken on 2,657 plants in 1932 and 1933.*

No. of nodes	Height in inches												Total No. plants
	21–23	24–26	27–29	30–32	33–35	36–38	39–41	42–44	45–47	48–50	51–53	54–56	
64–68							1	3	8	6	5	7	30
59–63						2	1	5	10	5	8	8	39
54–58					4	8	20	18	16	13	7	7	93
49–53				1	9	20	28	33	17	16	11	6	141
44–48				9	15	50	41	25	34	23	10	1	208
39–43			1	18	39	83	57	52	34	22	5	2	313
34–38			8	36	54	75	81	47	24	11	3	1	340
29–33	1	9	22	68	119	122	96	40	15	6	1		499
24–28	3	14	15	84	138	116	54	17	14	2			457
19–23	6	14	29	105	92	65	19	3	1	2			336
14–18	7	20	28	55	21	13	4	2	1				151
9–13	17	9	10	8	5		1						50
Total	34	66	113	384	496	554	403	245	174	106	50	32	2,657

$\bar{x} = 37.28$; $s = .13$: Height in inches per plant
$\bar{y} = 33.41$; $s = .22$: Nodes per plant
Correlation coefficient $(r) = +.6461$, representing high statistical significance.

rate during the period of August 5 to September 9 fell uniformly during each year. The rainfall and temperature varied considerably, however, during this period from year to year.

TABLE 2.—*Correlation of height of main stem of cotton plant with number of bolls, measurements taken on 4,679 plants in 1931, 1932, and 1933.*

No. of bolls	Height in inches									Total No. plants
	12–16	17–21	22–26	27–31	32–36	37–41	42–46	47–51	52–56	
25–27	0	0	0	3	5	4	4	6	1	23
22–24	0	0	2	5	7	23	15	17	4	73
19–21	0	0	3	12	18	51	39	28	6	157
16–18	0	3	16	20	78	131	111	46	21	426
13–15	2	4	37	50	221	311	156	66	23	870
10–12	0	24	77	115	439	311	122	48	16	1,152
7–9	5	73	148	222	431	236	77	24	12	1,228
4–6	45	113	84	142	167	52	32	4	2	641
1–3	40	26	8	16	14	3	2	0	0	109
Totals	92	243	375	585	1,380	1,122	558	239	85	4,679

$\bar{x} = 34.92$; $s = 1.19$: Height in inches per plant
$\bar{y} = 10.85$; $s = 0.65$: Bolls per plant.
Correlation coefficient (r) = +.4826, representing high statistical significance.

TABLE 3.—*Percentage of total bolls found in zone areas of the cotton plant, a zone including all bolls found on a particular node position of the fruiting limbs.*

Year	No. of plants measured	Zone A, first nodes	Zone B, second nodes	Zone C, third nodes	Zone D, fourth nodes	Zone E, fifth nodes	Zone F, sixth nodes	Zone G, seventh nodes	Zone H, vegetative
1931	512	58.23	27.55	7.01	0.64	0.12	0.06	0.02	6.37
1932	1,553	53.55	25.77	9.25	1.73	0.18	0.03	0.00	9.49
1933	1,197	46.33	24.47	11.33	3.24	0.25	0.13	0.00	14.25

It has been stated that Brody (3) gave a graphic method of calculating k, or relative growth rate, in percentage. In Fig. 3A the mean height of five plants of a variety are plotted as a sigmoid curve, while in Fig. 3B the same data are plotted by use of semi-log paper. It may be seen that a straight line fits the points from the fourth week, July 1, to the ninth week, August 5. During this period the plant made its most rapid growth. The relative growth-rate for this period is then calculated by Brody's method to be 28.4%.

The portion of the sigmoid curve representing the most rapid growing period in the life of the cotton plant is linear when plotted

TABLE 4.—*Mean gain in height of cotton plants at Knoxville, Tenn., 1931–38, measurements taken at weekly intervals.*

Year	No. of plants measured	Initial height June 10, in.	Height in inches												
			June 17	June 24	July 1	July 8	July 15	July 22	July 29	Aug. 5	Aug. 12	Aug. 19	Aug. 26	Sept. 2	Sept. 9
1932	15	5.4	2.5	3.5	3.4	4.6	5.5	5.7	3.3	1.3	0.2	0.13	0.08	0.00	0.00
1933	30	6.3	2.0	3.0	3.6	3.2	3.0	3.9	4.7	3.1	2.1	0.60	0.25	0.02	0.00
1934	74	5.7	1.6	2.4	3.9	4.3	6.2	6.9	3.5	2.3	0.72	0.43	0.05	0.00	0.00
1935	125	4.0	1.0	1.6	2.7	2.9	4.5	5.4	6.9	7.5	3.9	1.6	0.64	0.11	0.04
1936	125	5.6	1.9	2.6	2.9	3.1	6.0	6.2	6.3	2.4	1.2	0.60	0.50	0.06	0.00
1937	125	4.3	1.3	2.5	3.8	4.1	4.9	5.1	5.5	4.0	3.0	2.5	1.6	0.50	0.07
1938	90	—	—	8.3*	2.6	3.7	4.1	5.9	8.3	7.2	6.2	3.1	0.40	0.20	0.00

*Initial height on this date.

on semi-log paper. Thus, it is assumed that the variable used in measuring this portion of curve might also be used to calculate some relationship with yield. The method of covariance as given by Snedecor (11) appeared to be the logical one to follow, because in arriving at a generalized regression coefficient it would be possible to set up the experiment in a way to eliminate partially varietal effects and soil variation. Five varieties commonly grown in the South were selected. The Latin square method of planting was used

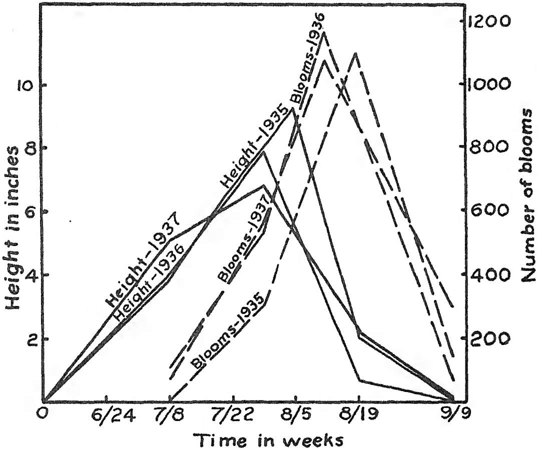

FIG. 2.—The maximum rate of plant growth as related to the peak of blooming.

on the same area each year, and the varieties located at random. the plots were three rows wide (9 feet) and 48 feet long. Five plants were selected at random for the growth rate measurements in the middle row of each plot. Hence, 25 plants for each variety were measured, or 125 plants for the experiment. In 1938, only three of the five varieties were used. The same procedure was followed as in the three preceding years, with the exception that 10 plants per plot were measured instead of five plants.

In Table 5 the independent variable, X values, representing relative growth rate in per cent, and the dependent variable, Y values, representing yield, are the means of five plants for each plot the first three years and of 10 plants in 1938. It may be seen in this table that for 2 years out of 4 the correlations within varieties are beyond the 1% level and of high statistical significance. In 1938 there is

TABLE 5.—*Covariances with X representing the independent variable, relative growth rate in percentage, and Y the dependent variable, yield per plant.*

Source of variation	1935				1936			
	Degrees of freedom	SX^2	SXY	SY^2	Degrees of freedom	SX^2	SXY	SY^2
Total......	24	35.12	0.5129	0.019355	24	100.44	1.8541	0.049500
Columns...	4	7.86	0.0721	0.000739	4	45.48	1.0451	0.024723
Rows......	4	2.14	0.0442	0.003336	4	0.88	0.0145	0.003818
Varieties...	4	4.48	0.1285	0.008859	4	18.49	0.1462	0.002131
Error......	12	20.64	0.2681	0.006421	12	35.59	0.6483	0.018828

	1935	1936
Regression coefficient	0.0130	0.0182
Correlation coefficient	0.7365	0.7920
Errors of estimate	29.39	70.18
Regression accounts for	54.2 % of SY^2	62.7 % of SY^2
E	0.0130 X − 0.2028	0.0182 X − 0.3376
$\bar{x}$	27.14%	25.74%
$\bar{y}$	0.150 pound	0.129 pound

Source of variation	1937				1938			
	Degrees of freedom	SX^2	SXY	SY^2	Degrees of freedom	SX^2	SXY	SY^2
Total......	24	148.72	3.0375	0.116772	8	18.98	0.2645	0.006718
Columns...	4	35.51	0.7095	0.018707	2	3.56	0.0393	0.000444
Rows......	4	7.88	0.1530	0.007096	2	4.31	0.0974	0.004025
Varieties...	4	60.88	1.9921	0.081421	2	10.73	0.1083	0.001106
Error......	12	44.45	0.1829	0.009548	2	0.38	0.0195	0.001143

	1937	1938
Regression coefficient	0.00412	0.0513
Correlation coefficient	0.2851	0.9375
Errors of estimate	87.95	1.42
Regression accounts for	7.9% of SY^2	87.5 % of SY^2
E	0.00412 X + 0.1096	0.0513 X − 1.243
$\bar{x}$	28.31%	26.54%
$\bar{y}$	0.226 pound	0.119 pound

only 1 degree of freedom for testing the correlation, and though this correlation is high, it is not significant. In the years 1935, 1936, and 1938, however, the regressions account for a fairly large portion of SY^2, or variation in yield. The data for the year 1937 give a poor correlation. This may be accounted for largely by a bad infestation of the tarnished plant bug. Although the data were not sufficiently extensive to make a sensitive test for non-linearity of the yield versus rapid growth rate, such tests showed non-significant departure from linearity, except in one case where the departure was barely significant. There seems to be a tendency for a high yield of a given year to be associated with a high relative growth rate of that year, but not enough yearly means are available on which to base an estimate of the significance of this tendency. In order to test further the

association between relative growth rate and yield, the estimates derived from calculations of data in Table 5 were used to obtain the calculated yields of other rows of each variety. These are shown in comparison with the actual yields in Table 6.

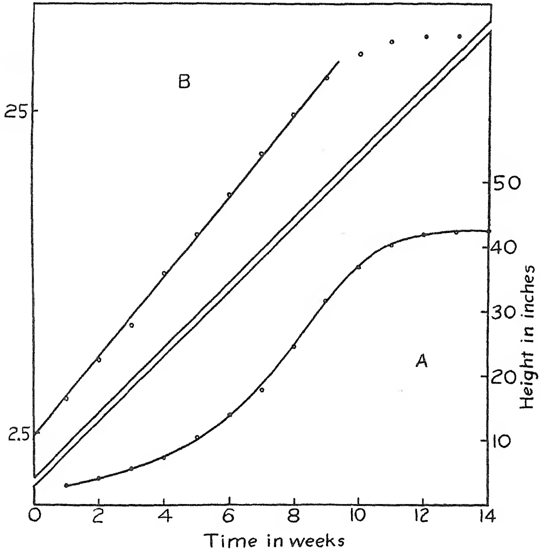

FIG. 3.—Growth rate plotted as in (A) the sigmoid and in (B) the logarithmic curve.

In Table 7 the relative daily growth rates of varieties as calculated in these studies are compared with those of Afzal and Iyer (1) for cotton varieties in India. Fairly typical years were taken. The growth rates were much the same. The weakness of their proposed formula, however, is that some varieties have considerably more seedling vigor than others, and consequently the initial height is greater, thereby causing a smaller difference between it and the final height.

DISCUSSION

Height and its association with yield in cotton should be considered with respect to varietal types. Some varieties are known to

have longer internodes than others. In Tennessee the shorter internode varieties usually give the best yields. For example, Stoneville with short internodes has yielded consistently more than Triumph with long internodes, yet both varieties have about the same height from year to year (5). This does not nullify the assumption, however, that taller Stoneville plants will give more yield than shorter Stoneville plants. Also, the data in Table 2 showing that the phenomenon of shedding is largely horizontal gives additional support to the assumption that height is a good measure of potential yield. It is emphasized, however, that the importance of height in these studies is found in the velocity of growth at a certain period of time.

TABLE 6.—*Total actual yields of five one-row plots compared with the calculated yields of each variety.*

Variety	1935		1936		1938	
	Actual yield, lbs.	Calculated yield, lbs.	Actual yield, lbs.	Calculated yield, lbs.	Actual yield, lbs.	Calculated yield, lbs.
Mebane Triumph	19.81	21.75	17.14	20.44	—	—
Wilds	17.03	20.19	15.38	18.20	—	—
Stoneville	18.90	21.58	23.06	20.62	—	—
Trice	17.19	19.62	18.44	16.09	20.60	17.74
Misdel	18.98	17.81	16.28	16.11	26.55	28.30
D. P. L. 10	—	—	—	—	24.76	27.30

TABLE 7.—*Comparison of average relative daily growth rate of varieties in these experiments with those reported by Afzal and Iyer in India.*

Variety	Knoxville, Tenn., 1935	Variety	India, 1931–32
Mebane Triumph	0.0283	4 F	0.0226
Misdel	0.0265	289 F	0.0241
Trice	0.0251	Early Strain	0.0255
Stoneville	0.0256	Mallisoni	0.0289
Wilds	0.0248		

No hypothesis is offered in this discussion for the forces activating or retarding the growth process. The more recent experiments on plant hormones cause many of the past theories to appear very doubtful. It is definitely established, however, that the sigmoid curve represents the manner of growth and that the three phases of this curve may be fairly well distinguished in the cotton plant.

The phase of growth of most importance from the standpoint of this paper is the high-velocity one, which at Knoxville comes in the period of July 1 to August 5. It was shown in Table 4 that this period did not vary much from year to year, but that the velocity within the period varied considerably. The velocity may be expressed in a linear form of the equation $H = Ae^{kt}$, and as such has been shown to be associated with yield (Table 5).

A severe insect infestation, as in 1937, if not controlled, will reduce the correlation. Under boll-weevil conditions, measurements of this kind might not be of any value, because the loss of the small fruiting buds might cause renewed growth of the plant.

The time period given for most rapid growth at other locations would likely differ from the one determined at Knoxville. Measurements would have to be taken at a number of places in a given state to determine this period. Also, this time period changes with the variety. In plotting the straight lines for percentages, sometimes the point of retarded growth fell before August 5 and in this case the July 29 point was used. It can be readily seen, too, that this time period would vary somewhat with abnormal dates of planting. Inmander, Singh, and Pande (7) took growth rates from plantings of cotton at different dates and found that the late plantings hastened the maximum increase in growth rate. In these experiments all the plantings were made at the normal date.

There are a number of possible relationships which space does not admit of reporting in detail. For instance, no adequate relationship was found between flower counts and yield, and flower counts do not add very much in a multiple regression. Green boll counts are of some value if growing conditions are normal during the early part of the reproductive period, but at Knoxville they come too late for an early estimate. The function which the growth rate of the fruiting limbs bears to that of the main stem should be valuable, but experiments are not complete as to the nature of this relationship.

Yates (12) has measured the height at heading-out time and number of plants at tillering on wheat in England. He reports some fairly accurate trends of association of these measurements with yield. In the studies at Knoxville, Tenn., a trend of association is shown between yield and measurements of the velocity of growth rate on the main stem of the cotton plant when taken during the most rapid growing period which is from July 1 to August 5. But the experiments would need to be carried over a number of years and a larger area before any definite trend could be substantiated.

SUMMARY

1. It has been shown that height of a mature cotton plant within varietal types is associated with its yield.

2. The curve representing the growth rate of the cotton plant is sigmoid, which confirms the results of other investigators.

3. The velocity of the growth curve based on data collected at Knoxville, Tenn., was found to be most rapid during the period of July 1 to August 5.

4. The exponential equation $H = Ae^{kt}$, when written in the linear form, was found to fit the data of this period well within experimental error.

5. The variable expressing the velocity of this period was found to be associated with yield and the departure from non-linearity was not significant in most cases.

6. Experiments testing the value of this tendency for estimating yields of cotton should be carried over a long period of years.

7. Plant measurements of this kind might be of some value in estimates of the cotton crop.

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DIFFERENT RATES OF CROSSING OVER IN MALE AND FEMALE GAMETES OF MAIZE[1]

M. M. Rhoades[2]

CROSSING over in maize occurs during micro- and megasporogenesis. A number of maize students, notably Emerson and Hutchison (7)[3], Eyster (9, 10), Stadler (20), and Collins and Kempton (3), have determined the relative frequency of crossing over in the two sexes. Emerson and Hutchison found a significantly higher percentage of crossing over for the *C-Sh* region of chromosome 9 in the female gametes of certain plants, but other data by these investigators and also by Eyster (10) show no significant differences in crossing over for this region in the two sexes.

Stadler found significantly higher crossover values for the *C-Sh*, *Sh-Wx*, and *C-Wx* regions in the male gametes.

Collins and Kempton reported a higher rate of crossing over for the *C-Wx* region in the male gametes of four progenies, while in nine progenies the female gametes had a higher percentage of crossing over. In six of the nine progenies with the higher female crossing over the differences are clearly significant, and in three of the four progenies where the male gametes had higher crossover percentages the differences are also significant.

Eyster (10) found no significant difference between the two sexes in recombination value for the *Su-Tu* region of chromosome 4. Emerson and Hutchison (7) reported a similar conclusion for the *Lg-B* region of chromosome 2.

Rhoades and Rhoades (17) found no marked differences in crossing over among the male and female gametes for three regions of chromosome 10.

The discordant results found by different investigators for the same region, the failure to find any difference in several regions, and the fact that where a difference was observed between the two sexes it was of such small magnitude that large numbers of individuals were necessary to establish its statistical significance all suggest that there is no consistent variation in crossing over associated with sex in maize. This generalization has been accepted by maize students, and usually no attempt has been made to indicate which parent was heterozygous when crossover values from backcrosses are reported.

This assumption led the writer to make an erroneous conclusion of the effect of a supernumerary chromosome on crossing over. In a study of a telocentric chromosome consisting of the short arm of chromosome 5, it was reported (15) that crossing over in the *Bm-Pr* region of chromosome 5 was significantly higher in plants hyperploid for the telocentric chromosome than in diploid sister plants. For technical reasons the percentage of crossing over in the *Bm-Pr*

[1]Contribution from the Department of Botany, Columbia University, New York City. Received for publication February 25, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 614.

region could be determined only among the male gametes of hyperploid plants. The recombination value for this region in the diploid siblings was obtained solely from the female gametes. The crossover value in the hyperploid individuals was found to be nearly twice as great as in the diploid siblings, and it was suggested, since there was no knowledge of a sex differential, that the unexpected and surprising difference might be caused in some inexplicable fashion by the redundant chromatin. Further investigations of the cause of this crossover difference were undertaken. These studies proved that the variation in crossover values between the hyperploid and diploid individuals lay in a differential crossover rate in the two sexes and was not a consequence of the presence of the supernumerary telocentric chromosome. A considerable body of data on the relative rates of crossing over in the two sexes has been obtained and will be presented in this paper.

EXPERIMENTAL RESULTS

According to Rhoades (16), the order and map positions of eight loci of chromosome 5 are as follows:

a2	*bm*	*bt*	*v3*	*bv*	*pr*	*ys*	*v2*
0	6	8	10	12	31	40	72

The *a2* and *bm* loci are known to lie in the short arm, while the other six genes are situated in the long arm of chromosome 5. Since only 1 to 2% of crossing over takes place between *Bm* and *Bt* and since they are on opposite sides of the centromere, either one of these loci can be used to mark the proximal ends of the two arms of chromosome 5. The *A2-Bm*, *A2-Bt*, *A2-Pr*, *Bm-Pr*, and *Bt-Pr* regions were studied. Tables 1 and 2 present the data obtained when only the *A2-Bt* region was followed.

The data in Table 1 are from the "low" line and consist of 16 pairs of crosses with a total population of nearly 10,000. It should be stressed that crossover values were determined in both the male and female flowers of the same individual to avoid any hetereogenity arising from possible genetic dissimilarity of different plants. Furthermore, exact direct and reciprocal crosses were made, that is, not only was the same heterozygous individual used as both male and female in each pair of crosses, but the same recessive tester plant was used as both the male and female parent. This procedure was followed in obtaining all the data reported in this paper. The data in Table 1 show there was a higher percentage of crossing over in the male flowers of each of the 16 heterozygous individuals tested. The differences ranged from 1.0 to 18.2%. The mean difference for the 16 pairs is 7.5%, and this is a highly significant value as shown by the t test given in Table 1.

In Table 2 are given the data for the recombination percentage between the same two genes in male and female gametes in a strain which has a relatively high level of crossing over as far as this region is concerned. The 10 pairs of exact and reciprocal crosses had a total population of over 6,000. The mean recombination value of 26.3%

TABLE 1.—*Crossing over between A2 and Bt in direct and reciprocal backcrosses (low line).* $\frac{A2\ Bt}{a2\ bt}$ $\times$ *a2 bt and reciprocal.*

Pedigree No. of F_1 plants	Sex	Gametic types				Σ	Crossover %	Increase in male gametes
		A2 Bt	*A2 bt*	*a2 Bt*	*a2 bt*			
4784 (3)	Male	96	15	13	114	238	11.8	+5.6
	Female	137	9	9	134	289	6.2	
4784 (6)	Male	208	38	43	217	506	16.0	+11.9
	Female	150	5	7	131	293	4.1	
4784 (9)	Male	162	23	16	156	357	10.9	+1.4
	Female	110	10	11	89	220	9.5	
4784 (7)	Male	310	43	54	370	777	12.5	+10.9
	Female	65	1	1	61	128	1.6	
4784 (15)	Male	143	16	19	144	322	10.9	+6.9
	Female	175	6	9	182	372	4.0	
4784 (23)	Male	196	23	29	227	475	10.9	+3.3
	Female	187	12	16	153	368	7.6	
4784 (26)	Male	57	10	7	76	150	11.3	+3.2
	Female	86	7	9	96	198	8.1	
4784 (27)	Male	123	13	21	125	282	12.1	+5.8
	Female	75	5	5	73	158	6.3	
4784 (28)	Male	63	9	6	47	125	12.0	+3.1
	Female	75	12	4	89	180	8.9	
4784 (31)	Male	187	25	30	171	413	13.3	+8.3
	Female	113	4	7	98	222	5.0	
4784 (34)	Male	82	16	7	78	183	12.6	+10.1
	Female	156	5	3	160	324	2.5	
4784 (2)	Male	115	10	10	136	271	7.4	+1.0
	Female	116	8	7	104	235	6.4	
4784 (a)	Male	155	35	34	169	393	17.6	+11.8
	Female	127	12	4	133	276	5.8	
4784 (12)	Male	263	47	56	306	672	15.3	+8.7
	Female	111	7	7	87	212	6.6	
4784 (13)	Male	112	37	46	148	343	24.2	+18.2
	Female	54	1	7	72	134	6.0	
4784 (b)	Male	76	13	19	106	214	15.0	+9.3
	Female	165	6	14	165	350	5.7	
		4,250	483	530	4,417	9,680	Av.♂ = 13.4 Av.♀ = 5.9	M.D. = 7.5

$$t = \frac{\text{M.D.}}{\text{S. E. M.D.}} = \frac{7.5}{1.15} = 6.5 \text{ (highly significant value)}$$

TABLE 2.—*Crossing over between A2 and Bt in direct and reciprocal backcrosses (high line).* $\frac{A2\ Bt}{a2\ bt} \times$ *a2 bt and reciprocal.*

Pedigree No. of F_1 plants	Sex	Gametic types				Σ	Crossover %	Increase in male gametes
		A2 Bt	A2 bt	a2 Bt	a2 bt			
4780 (11)	Male Female	61 72	16 22	18 15	48 67	143 176	23.8 21.0	+2.8
4780 (4)	Male Female	47 108	14 21	10 19	35 117	106 265	22.6 15.1	+7.5
4780 (15)	Male Female	61 76	15 13	27 16	53 62	156 167	26.9 17.4	+9.5
4780 (17)	Male Female	102 93	33 14	32 19	94 105	261 231	24.9 14.3	+10.6
4780 (23)	Male Female	160 160	54 19	50 34	140 148	404 361	25.7 14.7	+11.0
4780 (24)	Male Female	165 153	56 33	72 32	178 182	471 400	27.2 16.3	+10.9
4780 (A)	Male Female	129 177	64 33	75 44	137 169	405 423	34.3 18.2	+16.1
4780 (2)	Male Female	200 119	50 19	43 23	153 123	446 284	20.9 14.8	+6.1
4780 (10)	Male Female	99 130	35 37	29 36	106 114	269 317	23.8 23.0	+0.8
4780 (20)	Male Female	132 196	83 45	58 40	159 203	432 484	32.6 17.6	+15.0
		2,440	676	692	2,393	6,201	Av.♂ =26.3 Av.♀ =17.3	M.D. =9.03

$t = \frac{\text{M.D.}}{\text{S.E.}_{\text{M.D.}}} = \frac{9.03}{1.54} = 5.9$ (highly significant value)

among the male gametes is significantly greater than the mean of 17.3% among the female gametes. No analysis has yet been made of the genetic basis responsible for the difference between the high and low lines. It is possible that some structural change, such as a small inversion, has occurred and that the low line is heterozygous for this inversion. Be that as it may, the data clearly shows a significant difference in male and female crossing over in both the high and low lines which is independent of the factor or factors responsible for the different level of crossing over between the two lines.

Jenkins, according to Emerson, Beadle, and Fraser (8), reported 7% of recombination between *A2* and *Bt*. This value is of the same order as that found among the female gametes of the low line and is less than one-fourth the value for the male gametes of the high line.

It may be hazarded that Jenkins's data come from heterozygous female flowers because so low a value was found. Since significant differences between male and female crossover values were found in the four lines used in these investigations, it is quite probable, though admittedly not demonstrated, that all or most strains would show a similar difference for this chromosome. If this is true, it will make considerable difference in the length of the genetic map of chromosome 5 whether or not crossover values are determined from male or female flowers.

The *A2-Bt* region lies for the most part in the short arm of chromosome 5. Although *Bt* is in the long arm, it is so close genetically to *Bm*, which is in the short arm, that the great bulk of crossing over in the *A2-Bt* region occurs between *A2* and the centromere. In order to ascertain if a like difference in crossover values in the two sexes exists in the long arm, crossover data were obtained for the *Bt-Pr* and *Bm-Pr* regions. It was possible to study coincidentally crossing over in the *A2-Bt* and *A2-Bm* regions when the *Bt-Pr* and *Bm-Pr* values, respectively, were being obtained. The data from the direct and reciprocal backcrosses of heterozygous *A2-Bt-Pr* individuals are given in Table 3. The *A2 a2* alleles affect aleurone color, with the *A2* producing colored and *a2* giving colorless aleurone. *Bt bt* determine the quality and development of the endosperm and can be scored with accuracy with either *A2* or *a2*. The *Pr pr* alleles, however, determine whether the aleurone color will be purple or red—the *Pr* allele producing purple and *pr* red aleurone color—and hence can be classified only in *A2* seeds. Consequently, the colored class alone can be utilized in studying crossing over in the *A2-Pr* and *Bt-Pr* regions.

The data in Table 3 consists of 17 pairs of direct and reciprocal crosses having a total population of nearly 11,000 individuals. In the *A2-Bt* interval the mean amount of crossing in the male flowers was 16.5%, while it was only 9.7% on the female side. The difference of 6.8% is highly significant and is of the same order of absolute magnitude as the differences listed in Tables 1 and 2. The *Bt-Pr* region, lying in the long arm, is much longer than *A2-Bt*. The mean percentage of 35.4 was observed for the male gametes, while in the female flowers there was 30.3% of recombination. The absolute difference of 5.1% is similar to that of 6.8% found for the *A2-Bt* region. It is, of course, a proportionately much smaller increase.

A considerable mass of data from three point tests was obtained from direct and reciprocal backcrosses in which the *Bm* locus was followed in place of *Bt*. These data are given in Table 4. They show that in both the *A2-Bm* and *Bm-Pr* regions there is a highly significant increase of crossing over in the male flowers. A slight error may exist in the determination of the male crossover values given in Table 4. Sprague (19) has shown that occasionally sperm from two pollen tubes may be involved in the fertilization of a single ovule. A sperm from one pollen tube may unite with the egg, while a sperm from the second pollen tube may fuse with the polar nuclei to form the endosperm. Sprague called this phenomenon heterofertilization. When a heterozygous individual is used as the pollen parent, it may

TABLE 3.—*Crossover data from three point test involving regions in opposite arms of chromosome 5,* $\frac{A2\ Bt\ Pr}{a2\ bt\ pr}$ × *a2 bt pr and reciprocal.*

Pedigree No. of F_1 plants	Sex	(0) *A Bt Pr*	(1) *A bt pr*	(2) *A Bt pr*	(1–2) *A bt Pr*	(1) (1–2) *a Bt–*	(0) (2) *a bt–*	Σ	Crossover, % *A Bt* region	Crossover, % *Bt-Pr* region	Increase in male *A-Bt*	Increase in male *Bt-Pr*
7279 (1)	Male	76	9	54	8	21	146	314	12.1	42.2	+0.3	+14.1
	Female	120	21	59	4	25	195	424	11.8	28.1		
7279 (4)	Male	63	22	47	8	18	140	298	16.1	39.3	+7.8	+ 1.9
	Female	117	17	74	6	11	183	408	8.3	37.4		
7297 (33)	Male	59	20	42	21	33	114	289	25.6	44.4	+10.3	+13.3
	Female	125	30	59	11	26	187	438	15.3	31.1		
7279 (26)	Male	78	18	61	6	23	167	353	13.3	41.1	+2.7	+10.0
	Female	145	21	70	5	24	206	471	10.6	31.1		
7279 (22)	Male	49	11	33	7	24	126	250	16.8	40.0	+4.1	+3.4
	Female	107	18	61	11	24	196	417	12.7	36.6		
7279 (28)	Male	93	6	43	1	11	158	312	5.8	30.8	−3.6	−5.5
	Female	132	24	83	6	17	237	499	9.4	36.3		
7279 (27)	Male	126	40	68	11	45	207	497	19.3	32.2	+10.7	+1.9
	Female	119	17	56	3	13	179	387	8.6	30.3		
7279 (42)	Male	58	13	24	1	8	97	201	10.9	26.0	+0.7	+9.9
	Female	148	19	29	3	20	191	410	10.2	16.1		
7279 (34)	Male	81	17	54	9	28	155	344	15.7	39.1	+8.9	+12.6
	Female	124	15	50	0	8	140	337	6.8	26.5		

.279 (32)	Male	83	3	23	0	14	116	239	7.1	21.1	+3.0	−6.2
	Female	114	6	44	1	7	167	339	4.1	27.3		
7279 (9)	Male	46	13	32	6	12	109	218	14.2	39.2	+2.2	−0.5
	Female	93	18	65	8	15	142	341	12.0	39.7		
7279 (29)	Male	46	10	41	3	15	114	229	12.2	44.0	+8.6	+12.3
	Female	85	1	38	2	6	115	247	3.6	31.7		
7279 (37)	Male	44	17	22	13	21	86	203	25.1	36.5	+16.4	+3.9
	Female	77	10	39	3	8	105	242	8.7	32.6		
7279 (13)	Male	52	27	27	4	26	121	257	22.2	28.2	+10.8	+1.9
	Female	52	7	20	1	11	75	166	11.4	26.3		
7279 (3)	Male	61	11	27	4	19	92	214	15.9	30.1	+4.6	−4.5
	Female	76	9	43	2	17	101	248	11.3	34.6		
7279 (15)	Male	54	23	37	8	32	97	251	25.1	36.9	+11.0	+5.5
	Female	96	20	49	4	25	153	347	14.1	31.4		
7279 (20)	Male	70	32	38	6	26	110	282	22.7	30.1	+17.1	+12.4
	Female	178	12	40	1	13	221	465	5.6	17.7		
		3,047	557	1,552	187	646	4,948	10,937	Av.♂ = 16.5% Av.♀ = 9.7%	Av.♂ = 35.4% Av.♀ = 30.3%	M.D. = 6.8%	M.D. = 5.1%

A2–Bt region — $t = \frac{\text{M.D.}}{\text{S.E.}_{\text{M.D.}}} = \frac{6.8}{1.38} = 4.9$ (highly significant value)

Bt–Pr region — $t = \frac{\text{M.D.}}{\text{S.E.}_{\text{M.D.}}} = \frac{5.1}{1.61} = 3.2$ (highly significant value)

TABLE 4. *Crossover data from three point test involving regions in opposite arms of Chromosome 5,* $\frac{A2\ bm\ Pr}{a2\ Bm\ pr} \times a2\ bm\ pr$ *and reciprocal.*

Pedigree No. of F_1 plants	Sex	(0) *A bm Pr*	(1) *A Bm pr*	(2) *A bm pr*	(1–2) *A Bm Pr*	(1) (1–2) *a bm–*	(0) (2) *a Bm–*	Σ	Crossover, % *A-Bm* region	Crossover, % *Bm-Pr* region	Increase in male *A-Bm* region	Increase in male *Bm-Pr* region
6484 (6)	Male	68	19	51	15	28	117	298	20.8	43.1	+7.8	+6.3
	Female	109	18	65	9	26	181	408	13.0	36.8		
6484 (11)	Male	54	24	47	6	21	81	233	21.9	40.5	+9.2	+14.2
	Female	132	19	48	6	26	172	403	12.7	26.3		
6484 (7)	Male	66	18	34	13	25	114	270	20.7	35.9	+13.4	+8.7
	Female	119	12	46	3	10	151	341	7.3	27.2		
6484 (30)	Male	109	15	51	9	22	161	367	12.5	32.6	+2.4	+4.6
	Female	122	14	51	2	25	190	404	10.1	28.0		
6484 (19)	Male	81	24	55	16	31	154	361	19.7	40.3	+3.5	+11.2
	Female	90	17	36	8	24	128	303	16.2	29.1		
6484 (14)	Male	95	21	61	13	34	146	370	18.4	39.0	+7.5	+6.1
	Female	90	8	43	5	18	120	284	10.9	32.9		
4799 (12)	Male	43	4	12	0	8	65	132	9.1	20.3	+7.9	+8.9
	Female	69	1	9	0	1	82	162	1.2	11.4		
4799 (4)	Male	90	6	17	3	2	108	226	4.9	17.2	–0.8	+7.5
	Female	163	5	17	1	16	187	389	5.7	9.7		
5509 (14)	Male	128	25	73	12	25	255	518	12.0	35.7	+7.0	+17.6
	Female	272	14	62	1	19	322	690	5.0	18.1		
		1,900	264	778	122	361	2,734	6,159	Av.♂ = 15.6 Av.♀ = 9.1	Av.♂ = 33.8 Av.♀ = 24.4	M.D. = 6.5	M D. = 9.4

A2–Bm region — $t = \frac{\text{M.D.}}{\text{S.E.}_{\text{M.D.}}} = \frac{6.5}{1.4} = 4.6$ (highly significant value)

Bm–Pr region — $t = \frac{\text{M.D.}}{\text{S.E.}_{\text{M.D.}}} = \frac{9.4}{1.4} = 6.8$ (highly significant value)

lead to different genetic constitution of the embryo and endosperm. If all the characters under investigation are expressed either in the endosperm or in the sporophyte, the occurrence of heterofertilization is not a source of error. However, in the case of the *A2-Bm-Pr* data we are concerned with two endosperm and one sporophyte character, and in these data heterofertilization would increase the observed amount of recombination. Fortunately, the frequency of heterofertilization could be determined, since the *A2* and *a2* alleles affect both aleurone and plant color. It proved to be low. The greater portion of the differences in male and female crossing over in the *A2-Bm* and *Bm-Pr* regions are clearly associated with sex and are not specious differences resulting from a high frequency of heterofertilization.

The data in Tables 1 to 4 show conclusively that differences in crossing over exist between the male and female flowers in certain regions of chromosome 5. The three point data given in Tables 3 and 4 permit the calculation of coincidence values. The *A2-Bt* and *A2-Bm* regions may be considered as lying in the short arm, while *Bt-Pr* and *Bm-Pr* are in the long arm of chromosome 5. It is known that in *Drosophila melanogaster* the two arms of both the second and third chromosomes behave as independent units in that interference in crossing over does not extend from one arm to the other across the centromere. If a similar situation is found in maize, we should expect to find coincidence values of approximately 1.0 for the *A2-Bt-Pr* and *A2-Bm-Pr* data. The coincidence value of 0.8 calculated from the data in Table 3 and the value of 1.1 for data in Table 4 indicate that in maize as in Drosophila the two arms of a chromosome act as independent units. A study of coincidence values in the male and female data of Tables 3 and 4 showed no significant differences in interference values between the two sexes.

No pronounced or consistent difference in crossing over was found associated with sex for three regions in the short arm of chromosome 9 (7, 20, 3), nor was any found for several regions in various chromosomes. The data presented in this paper are at variance with data of earlier investigators. It seemed possible that the differences observed between male and female crossover values for chromosome 5 might be produced by some general cellular agent affecting all chromosomes alike. To test this possibility, crossing over in the *C-Wx* region of chromosome 9 was studied in the same strains in which values for the *Bm-Pr* region were being determined. No marked or consistent difference in the *C-Wx* region was found among the male and female gametes, so it may be concluded that the differences found in the regions studied of chromosome 5 are the result of some peculiarity inherent in this chromosome. Additional evidence arguing against the presence of a general cellular agent is that the data in Tables 1 to 4 come from diverse strains, and it would be somewhat improbable that these four unselected strains possessed such a disturbing factor when all previously tested strains lacked it.

DISCUSSION

The data in Tables 3 and 4 show that the absolute increases in crossing over in the male flowers for the relatively short *A2-Bt* and *A2-Bm*

regions are approximately equal to those found for the longer *Bt-Pr* and *Bm-Pr* regions. The *A2-Bt* and *A2-Bm* regions may be considered as lying in the short arm of the chromosome, and the longer two regions as situated in the other arm. It is possible that the differences associated with sex in these regions are confined to those segments adjacent to the centromere and that there is no effect in more distally placed regions of both arms of this chromosome. The proportionately smaller increases in crossing over among the male gametes for the longer *Bt-Pr* and *Bm-Pr* regions may arise from the fact that the *Pr* locus lies considerably beyond the proximally placed differential region of the long arm and that equal amounts of crossing over occur in the male and female flowers in the more distal portions of these two regions. It is of course quite likely that a different degree of cross-over inequality between the male and female flowers exists in the two arms of chromosome 5. However, the concept that the difference in crossover values in the two sexes is confined to those regions adjoining the centromere is subject to experimental check, since on this hypothesis no sex differences in crossover values would be found in the more distal regions.

The causes of this difference in crossing over in the male and female gametes are unknown. The suggestion has been made that the sex difference is confined to those regions adjacent to or including the centromere. This infers that this differential effect is under centric control but leaves unexplained why the centromere should have differing effects in the two kinds of flowers on the same individual. There are no published data for maize which controvert the idea that the differential crossing over between the two kinds of gametes is confined to those regions close to the centromere. While no exact information on the physical location of the various loci followed in earlier maize investigations is at hand, it is known that the *Lg-B* region lies well out in the short arm of chromosome 2 (14), that *C-Wx* lies wholly within the short arm of 9, some distance removed from the centromere (McClintock, unpublished), and it is quite probable that the *R*, *G*, and *Li* loci are all in the long arm of chromosome 10, since *R* is known to be within one or two crossover units of the distal end of the long arm (Rhoades, unpublished).

At pachytene the regions of the two arms of chromosome 5 contiguous to the centromere have deep-staining, heteropycnotic chromomeres. (See Rhoades, 16, fig. A, plate 2.) At least part of the *A2-Bm*, *A2-Bt*, *Bt-Pr*, and *Bm-Pr* regions are comprised of these pycnotic regions. The difference in crossing over associated with sex may be confined to these pycnotic regions. Crossing over may not occur so frequently in pycnotic regions as in euchromatic ones, and it is possible that in microsporocytes a lesser degree of pycnosis occurs in the proximal parts than in megasporocytes and that this is reflected in a higher cross-over frequency in the male flowers. The 10 maize chromosomes possess differing numbers of deep-staining chromomeres adjacent to the centromere, so the various chromosomes might vary in the extent to which crossover differences occur in these proximal regions in male and female flowers. Mather (13) has shown that crossing over in the heterochromatic portion of the X

chromosome of *Drosophila melanogaster* is much more affected by environmental conditions than is the euchromatin. Since the male and female flowers of maize are widely separated on the plant and the deep-lying ovules are more protected, it may be that they develop in unlike environments. It is realized of course that all of the above is highly speculative. There can be no reasonable doubt, however, that for certain regions of chromosome 5 crossover differences between the male and female flowers do exist no matter what the underlying cause may be.

The difference in crossing over in the male and female flowers of the same individuals for chromosome 5 are not directly comparable to differences found between the sexes of non-hermaphroditic organisms. In these unisexual forms it appears to be the rule that where differences in crossing over exist it is the heterogametic sex which inhibits crossing over. This generalization was made by Haldane (11), and surveys made of existing data support this statement. For example, in Drosophila crossing over in the heterogametic male is a rare event, while no crossing over occurs in the females of Bombyx which are the heterogametic sex (21, 22). Smith (18) also found that no crossing over took place in the female wax moth Galleria. In a number of animals crossing over takes place in both sexes but with a lower frequency in the heterogametic sex.

Hollander (12), in a study of three linked autosomal factors, found that crossing over was greatly reduced in the female pigeon which is the heterogametic sex.

Dunn (6), Castle (2), and others have shown that crossing over is more frequent in female than in male mice and rats. Crew and Koller (4) and Bryden (1) have made comparative studies of chiasma frequency in male and female mice and rats and found a lower chiasma frequency in the heterogametic male meiocytes. While these observations parallel the genetic results, it should be remembered that they determined the mean chiasma frequency of all bivalents and not for the specific regions followed in the genetic investigations nor even for the chromosomes containing these specific regions, and it is possible that one region might show higher crossover values in one sex while another region would have higher values in the opposite sex. This is precisely the situation found in Primula where DeWinton and Haldane (5) reported that two regions had higher recombination values in the megasporocytes while two other regions had smaller values on the female side.

Warren (23) in a review of the data on crossing over in the fowl, where the female is the heterogametic sex, concluded there was no difference in autosomal crossing over in the two sexes.

Emerson and Hutchison (7) are correct in pointing out that the study of crossover differences in male and female gametes of hermaphroditic plants is not quite the same as in dioecious plants or in animals where the two sexes are sharply separated. No case is known in a hermaphroditic plant where crossing over is inhibited in one sex and not in the other, and in most plants no consistent differences in male and female crossing over have been reported, for example, Pisum, Pharbitis, Datura, Lycopersicon, although

certain differences between the male and female gametes have been established in maize and Primula.

SUMMARY

Crossing over was studied in the *A2-Bt*, *A2-Bm*, *Bt-Pr*, and *Bm-Pr* regions of chromosome 5 of maize. The first two regions lie in the short arm of chromosome 5, while the latter two lie in the long arm. The *Bt* and *Bm* loci were used to mark the centromere since they lie in opposite arms and are very closely linked. Exact direct and reciprocal backcrosses were made, giving a total population of about 33,000 individuals.

The frequency of crossing over in the male flowers for the four regions studied was significantly higher than in the female flowers. This inequality is in contrast to the results of previous maize investigators studying different regions from those followed here. The suggestion is made that only those regions adjacent to the centromere will show a crossover difference associated with sex.

Three point tests where the two regions lay in opposite arms showed that interference does not extend across the centromere. This is in agreement with the Drosophila data.

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GROUPING OF STRAINS OR VARIETIES BY USE OF A LATIN SQUARE[1]

WILLIAM DOWELL BATEN, JACK I. NORTHAM, AND A. F. YEAGER[2]

DURING the summer of 1939, 64 strains of tomatoes were planted at the Michigan Agricultural Experiment Station in a Latin square in which there were four rows and four columns. The strains were divided into four groups of 16 strains each in order to make comparisons between groups, between strains in the same group, and between strains in different groups. Each cell of the Latin square contained one group of 16 strains. The design contained four replications. Fig. 1 shows the design for the groups I, II, III, and IV, together with plot and group yields. This is not the original random layout. The 16 strains in each group were planted at random in their respective cells of the Latin square.

PART I

To determine whether or not the data could be pooled to estimate an experimental error, an analysis of variance was carried out in each group, considering that each group was in a randomized block layout.

On examining the error variances in Table 1, it appears as though they are not homogeneous. To determine whether or not these error variances are homogeneous Bartlett's (2)[3] test was used. This test, as given by Rider (5), is

$$X^2 = \frac{2.3026}{C}\left[n \log_{10} s^2 - \sum_{i=1}^{k} n_i \log_{10} s_i^2\right],$$

where $n_i = 45$, $(i = 1, 2, 3, 4)$; $n = \Sigma n_i = 180$;

S_i^2 = error variance for the ith group;

$$S^2 = \frac{\Sigma n_i S_i^2}{n}, \quad k = 4 \text{ and}$$

$$C = 1 + \frac{1}{3(k-1)}\left[\Sigma \frac{1}{n_i} - \frac{1}{n}\right].$$

These values as found from the data are as follows:

$$\begin{aligned}
S_1^2 &= 20.10, & \log S_1^2 &= 1.30320, \\
S_2^2 &= 32.45, & \log S_2^2 &= 1.51121, \\
S_3^2 &= 67.99, & \log S_3^2 &= 1.83245, \\
S_4^2 &= 36.58, & \log S_4^2 &= 1.56324, \\
\Sigma S_i^2 &= 157.12, & \Sigma \log S_i^2 &= 6.21010
\end{aligned}$$

$$S^2 = 45\, \Sigma S_i^2/180 = 39.28$$

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[3]Figures in parenthesis refer to "Literature Cited", p. 622.

Columns

(1)	(2)	(3)	(4)	(33)	(34)	(35)	(36)	(49)	(50)	(51)	(52)	(17)	(18)	(19)	(20)
20.5	17.9	21.8	20.9	27.9	31.6	29.8	26.7	29.2	32.5	51.7	34.8	19.8	31.7	20.6	6.8
(5)	(6)	(7)	(8)	(37)	(38)	(39)	(40)	(53)	(54)	(55)	(56)	(21)	(22)	(23)	(24)
14.8	23.3	22.4	14.7	34.9	30.2	29.0	32.0	26.5	32.2	20.1	22.5	39.2	29.0	19.0	24.8
	I (327.6)				III (522.3)				IV (428.6)				II (518.2)		
(9)	(10)	(11)	(12)	(41)	(42)	(43)	(44)	(57)	(58)	(59)	(60)	(25)	(26)	(27)	(28)
18.7	20.1	16.5	17.6	44.8	35.6	31.0	24.9	29.8	7.6	27.3	23.6	43.8	42.7	45.8	45.6
(13)	(14)	(15)	(16)	(45)	(46)	(47)	(48)	(61)	(62)	(63)	(64)	(29)	(30)	(31)	32)
26.5	35.8	21.1	15.0	27.4	34.3	42.6	39.6	5.0 [23.1]	28.7	38.3	18.8	18.3	35.3	42.7	53.1)
(17)	(18)	(19)	(20)	(49)	(50)	(51)	(52)	(1)	(2)	(3)	(4)	(33)	(34)	(35)	(36)
21.3	28.3	15.6	18.0	35.8	40.4	38.8	35.6	38.2	25.0	20.7	24.4	46.8	47.3	67.3[29.1]	35.2
(21)	(22)	(23)	(24)	(53)	(54)	(55)	(56)	(5)	(6)	(7)	(8)	(37)	(38)	(39)	(40)
27.5	14.2	15.4	20.2	23.7	24.7	36.8	30.4	9.8	27.6	19.2	19.1	34.3	25.0	33.5	36.7
	II (429.0)				IV (456.0)				I (398.0)				III (576.7)		
(25)	(26)	(27)	(28)	(57)	(58)	(59)	(60)	(9)	(10)	(11)	(12)	(41)	(42)	(43)	(44)
30.3	25.9	33.9	26.0	14.3	23.9	25.5	23.7	22.3	16.4	28.5	34.2	35.9	21.8	37.5	26.2
(29)	(30)	(31)	(32)	(61)	(62)	(63)	(64)	(13)	(14)	(15)	(16)	(45)	(46)	(47)	(48)
25.3	37.8	43.5	36.8	25.3	27.0	34.4	15.7	19.4	40.3	35.6	17.3	30.6	33.8	33.9	30.9
(33)	(34)	(35)	(36)	(1)	(2)	(3)	(4)	(17)	(18)	(19)	(20)	(49)	(50)	(51)	(52)
29.3	38.4	21.3	43.1	30.2	21.3	23.0	22.6	18.5	21.7	26.1	9.7	33.6	28.5	41.6	24.5
(37)	(38)	(39)	(40)	(5)	(6)	(7)	(8)	(21)	(22)	(23)	(24)	(53)	(54)	(55)	(56).
25.7	35.1	26.8	40.1	14.7	23.6	21.4	13.1	23.8	23.2	20.5	19.9	23.5	29.7	27.4	27.3
	III (502.9)				I (365.3)				II (444.5)				IV (396.9)		
(41)	(42)	(43)	(44)	(9)	(10)	(11)	(12)	(25)	(26)	(27)	(28)	(57)	(58)	(59)	(60)
22.2	40.2	25.8	32.4	22.6	17.2	26.3	19.0	38.9	40.4	33.9	36.2	24.1	17.8	21.8	19.5
(45)	(46)	(47)	(48)	(13)	(14)	(15)	(16)	(29)	(30)	(31)	(32)	(61)	(62)	(63)	(64)
19.8	34.8	38.7	29.2	29.8	31.2	35.1	14.2	18.0	47.3	37.0	29.4	23.5	16.4	24.4	13.3
(49)	(50)	(51)	(52)	(17)	(18)	(19)	(20)	(33)	(34)	(35)	(36)	(1)	(2)	(3)	(4)
45.7	27.6	37.7	29.8	15.6	23.7	15.6	4.9	8.6[34.0]	34.0	31.2	30.4	36.3	21.5	18.5	18.2
(53)	(54)	(55)	(56)	(21)	(22)	(23)	(24)	(37)	(38)	(39)	(40)	(5)	(6)	(7)	(8)
21.5	30.6	16.0	20.1	22.3	13.2	27.8	19.3	21.9	31.6	22.6	35.8	7.4	20.6	15.9	19.4
	IV (394.1)				II (387.9)				III (484.6)				I (365.2)		
(57)	(58)	(59)	(60)	(25)	(26)	(27)	(28)	(41)	(42)	(43)	(44)	(9)	(10)	(11)	(12)
26.4	12.8	36.6	22.5	27.0	25.4	26.8	38.5	33.7	29.1	30.2	25.3	18.1	17.9	27.3	30.1
(61)	(62)	(63)	(64)	(29)	(30)	(31)	(32)	(45)	(46)	(47)	(48)	(13)	(14)	(15)	(16)
14.8	15.2	23.5	13.3	21.1	30.6	36.5	39.6	33.5	41.3	38.6	36.8	20.2	33.9	32.1	27.8

FIG. 1.—Tomato strain yields in a Latin square arranged for computing purposes. Strain numbers in parenthesis; yields in pounds; group totals in center.

$$C = 1 + \frac{1}{3(3)}\left[\frac{4}{45} - \frac{1}{180}\right] = 1.01$$

$$X^2 = 2.28[180 \log 39.28 - 45(6.21010)] = 17.09.$$

On entering a X^2-table at 3 degrees of freedom it is found that the X^2 at the one per cent point is 11.34, which is less than that found in this case. Hence the error variances are not homogeneous and the corresponding sums of squares should not be pooled to obtain an estimate of error. On examining the data, it was found that the data would be homogeneous if certain strains were omitted.

TABLE 1.—*Analyses of variances of strain yields of the four groups.*

Source of variation	D. F.	Groups							
		I		II		III		IV	
		Sum of squares	Mean square	Sum of squares	Mean square	Sum of squares	Mean square	Sum of squares	Mean square
Total.....	63	3,192.4	—	7,188.6	....	4,267.1	....	5,066.3	—
Replications...	3	155.3	51.8	576.4	192.1	297.2	99.1	160.7	53.6
Strain....	15	2,132.6	142.2	5,151.9	343.5	910.5	60.7	3,259.5	217.3
Error.....	45	904.5	20.1	1,460.3	32.5	3,059.4	68.0	1,646.3	36.6

The method will be explained for determining which strains to omit in group III. The variance of the yields from each strain in this group was found. After Bartlett's test was applied to these 16 variances, it was found that they were not homogeneous. On examining these variances, it was found that the variances pertaining to the yields of strains Nos. 33 and 35 were causing the trouble because they were so large compared to the others. On applying Bartlett's test to the variances after omitting Nos. 33 and 35, there was no evidence of heterogeneity.

On examining the variances of the other groups in a similar way, it was found that no heterogeneity appeared among the strain variances within the group. To have the same number of strains in each group it was decided to omit two strains from each group since two had been omitted from group III. The two strains in each of groups I and II were taken out at random. Strains Nos. 1 and 12 were omitted from group I; Nos. 26 and 32 from group II; Nos. 33 and 35 from group III; and Nos. 55 and 61 from group IV. No. 61 was omitted because it had a very low yield in the third replication. No. 55 was taken out at random. The Latin square now consisted of four groups with 14 strains in each group.

On analyzing the data similar to that in Table 1 and on applying Bartlett's test again to the error variances, no evidence of heterogeneity was found, hence the error *sums of squares* were pooled to form an estimate of error. The final analysis of variance for this Latin square with 14 strains in each group is given in Table 2. The

total *sum of squares*, the *sums of squares* between rows, columns, and groups are found in the usual way.

The *sum of squares* between strain means is found by adding the *sum of squares* between strain means for each group. The *sum of squares* between strain means in group I is found by carrying out a separate analysis of variance on the yields of the strains in group I, considering that these 14 strains are layed out in a randomized block design. This kind of analysis was carried out for the yields in each of the other groups. The last error *sum of squares* in Table 2 is found by adding the four *sums of squares* for error for each group or by subtracting from the total *sum of squares* in Table 2 the other sum of square terms.

Since this layout is a split plot design with two plot sizes (plots containing groups and plots containing strains), there are two error variances in Table 2. The first error variance, designated by (a), is

TABLE 2.—*Analysis of variance of strain yields of tomatoes.*

Source	D. F.	Sum of squares	Mean square	Standard error
Total	223	17,767.21	—	—
Rows	3	225.58	—	—
Columns	3	76.84	—	—
Groups	3	3,183.28	1,061.09	—
Error (a)	6	293.28	48.88	6.99
Strains	52	9,755.99	187.62	—
Error (b)	156	4,232.24	27.13	5.21

for comparing the group means and the second error variance, designated by (b), is for comparing the means of strains within a group. A third error variance is obtained from a combination of these two and is used for comparing means of strains not in the same group. The group means are as follows:

Groups	Group means, lbs.	Mean yield per strain, lbs.
I	307.50	21.96
II	369.33	26.38
III	456.08	32.58
IV	576.68	26.91

The standard error for each group mean is $6.99/\sqrt{4}=3.49$ pounds, where the value 6.99 is the error (a) in Table 2. The standard deviation of the difference between any two group means is 4.93 pounds. The difference to be significant at the 5% point is 12.06 pounds, which is found by multiplying 4.93 by 2.447, which is found at the value of t in the t-table at the 5% point. The mean of group I is significantly smaller than the means of the other groups and the mean of group III is significantly larger than the means of the other groups.

The standard error of any mean in any group is $5.21/\sqrt{4}=2.61$ pounds, where 5.21 is the error (b) in Table 2. The standard deviation of the difference of any two means in the same group is $5.21/\sqrt{2}=$

3.68 pounds; the difference between two means in the same group to be significant is equal to $3.68 \times 1.976 = 7.27$ pounds. The value 1.976 was found in the *t*-table at 156 degrees of freedom.

The standard error of the difference between any two means in different groups (4) is

$$\sqrt{\frac{2}{4 \times 14}\left[6.99^2 + 13(5.21)^2\right]} = 3.79 \text{ pounds,}$$

which is a weighted standard error. The difference between two means in different groups to be significant is equal to

$$3.79 \times 1.976 = 7.49 \text{ pounds (156 degrees of freedom)}$$

or

$$3.79 \times 1.975 = 7.49 \text{ pounds } (156 + 6 = 162 \text{ degrees of freedom}),$$

where the value 1.975 was found in a *t*-table at 162 degrees of freedom. In this case it makes no difference whether one enters the t-table at 156 or 162 degrees of freedom. By using the above differences to be significant one can determine which strains are best. The mean for each strain is given in Table 3. This analysis does not include strains Nos. 1, 12, 28, 32, 33, 35, 55, and 61.

TABLE 3.—*Strain means for each group in pounds.*

Group I		Group II		Group III		Group IV	
No.	Average	No.	Average	No.	Average	No.	Average
1	31.3*	17	18.8	33	34.5*	49	36.1
2	21.4	18	26.4	34	37.8	50	32.3
3	21.0	19	19.5	35	27.9*	51	42.5
4	21.5	20	9.9	36	33.9	52	31.2
5	11.7	21	28.2	37	29.2	53	23.8
6	23.8	22	19.9	38	30.5	54	29.3
7	19.7	23	20.7	39	28.0	55	25.1*
8	16.6	24	21.1	40	36.2	56	25.1
9	20.4	25	35.0	41	34.2	57	23.7
10	17.9	26	33.6*	42	31.7	58	15.5
11	24.7	27	35.1	43	31.1	59	27.8
12	25.2*	28	36.6	44	27.2	60	22.3
13	24.0	29	20.7	45	27.8	61	21.7*
14	35.3	30	37.8	46	36.1	62	21.8
15	31.0	31	39.9	47	38.5	63	30.2
16	18.6	32	39.7*	48	34.1	64	15.3

*Used in part II.

PART II

On examining the yields in each plot of the 64 strains, it is found that No. 33 in the third column and the fourth row produced 8.6 pounds which was one less than one third of any of its yields in the other plots. Strain No. 35 produced in the fourth column and second row 67.3 pounds which was more than twice as large as any of its other yields. As mentioned in part I the variances of the yields pertaining to these strains were so large in relation to the variances of the yields of the other strains in group III that evidence of heterogeneity appeared. For these reasons it was thought best to estimate

these values by formula (1, 3, 6, 7) for estimating missing values. This was done by considering group III as a randomized block layout and then applying the formulas for missing plots. These estimates are shown in brackets in Fig. 1. They are more in harmony with the other three plot yields of Nos. 33 and 35 than the ones observed. An estimate was also made for the plot yield of strain No. 61 in the third column and first row of the Latin square. This value is 23.1 pounds which replaces the value of 5.0 pounds (1).

An analysis of variance was carried out on the data in each group, each of which now contained 16 strains, similar to Table 1, allowances being made in the degrees of freedom for groups III and IV because of estimating certain plot yields. On applying Bartlett's test to determine whether or not the error variances are homogeneous, it was found that there was no evidence of heterogeneity among them; hence the error *sums of squares* could be pooled for determining an estimate of error or experimental error. The complete final analysis of variance is given in Table 4.

TABLE 4.—*Analysis of variance of tomato strain yields.*

Source	D. F.	Sum of squares	Mean square	Experimental error
Total	252*	20,544.6	—	—
Rows	3	286.6	95.5	—
Columns	3	290.6	96.9	—
Groups	3	3,042.9	1,014.3	—
Error (a)	6	398.0	66.3	8.1
Strains	60	11,083.3†	184.7	—
Error (b)	177*	5,443.2	30.8	5.5

*Because of estimating certain plots.
†Found by adding the sums of squares due to strains.

The following values are the means of the groups:

Group	Group mean, lbs.	Mean yield per strain, lbs.
I	364.03	22.75
II	442.65	27.67
III	518.43	32.40
IV	423.43	26.46

The standard error for the difference between any two group means is

$$8.1\sqrt{1/4+1/4}=5.7 \text{ pounds.}$$

The value of the difference of group means to be significant at the 5% point is 13.9 pounds which is greater than the corresponding value in the first part. It is seen that the mean of group I is significantly smaller than the means of the other groups and that the mean of group III is significantly larger than the means of the other groups.

The standard deviation of the difference between any two means in the same group is equal to

$$5.5\sqrt{1/4+1/4}=3.89 \text{ pounds,}$$

and the value of the differences to be significant at the 5% point is equal to 7.68 pounds, which is larger than the corresponding value

in part I. On examining the means within each group in Table 3, it is found that the mean of No. 14 is significantly larger than the other means in group I, except the mean of No. 15; that the means of Nos. 28, 30, 31, and 32 are significantly greater than the other means in group II and the mean of No. 20 less than the others in this group; that Nos. 54 and 47 are better than Nos. 35, 37, 39, 44, and 45; and that strain 51 is the best in group IV. These results are very similar to the corresponding results in part I.

The standard deviation of the difference between any two means in different groups is

$$\sqrt{\frac{2}{4\times 16}\left[8.1^2+15(5.5)^2\right]}=4.03 \text{ pounds}$$

with $183=177+6$ degrees of freedom or 177 degrees of freedom. The differences between any two means in different groups to be significant are respectively 7.96 pounds and 7.95 pounds which are larger than the corresponding results in part I.

The method given in part II may be more desirable than that given in part I as it allows comparisons to be made between all of the strain yields, although three observed values were replaced by estimates.

The design explained here provides an excellent way of comparing groups, strains within each group, and different strains.

SUMMARY

A Latin square design is explained in which the cells are made up of groups of strains of tomatoes.

A test for homogeneity was applied to the variances to determine whether or not certain *sums of squares* could be pooled to obtain an estimate of error.

Applications were made showing how to test between means of strains within the same group and between means of strains in different groups.

A method is presented for analyzing the entire Latin square after estimating yields for certain plots which appeared to be extraordinary.

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SOIL TESTING METHODS AND APPARATUS DESIGNED FOR ECONOMY IN TIME AND LABOR[1]

E. W. CONSTABLE AND I. E. MILES[2]

SOIL testing for plant food deficiencies is seasonal in demand. To be true, there is some testing done at all seasons, considerable in the fall, but by far the bulk of the work is done during the spring months. If the testing and subsequent fertilizer recommendations are to be of value for the current crops, the laboratory work must proceed very rapidly and without sacrifice in accuracy of methods. It was with this in mind that an effort was made to economize labor and time by means of improved technics and equipment (3).[3]

In view of economy and facility, the design of specialized equipment includes, as far as possible, the adaptation of commonly available materials. In part, a type of application previously employed in these laboratories with appreciable economy (1) is followed.

METHODS AND EQUIPMENT

SOIL SAMPLES

Soil samples are received in a preparation room. After numbering and recording essential information, they are emptied into shallow, 10 by 10 inch baking pans for partial drying. Following this, all lumps are crushed, the samples put through a 2-mm, round-hole screen, and then returned to the original containers. Here, as well as in transportation, proper containers play an important part.

In proper containers samples retain considerable moisture for several days and in this state more nearly approximate field conditions; consequently, classification as to series, texture, drainage, etc., is facilitated. Also, one size and shape of container permits the systematizing of laboratory equipment.

A pint size, breakdown type, waxed, cardboard container was adopted (Fig. 1). The flap of the container is left unwaxed so as to permit writing upon it for the purpose of identification. On this flap space is provided for the farmer's name, the number or name of the field, and a laboratory number. All other external parts and all of the inside of the carton are waxed so as to retain the moisture of the soil. Instructions for collecting the soil samples are printed on the outside. In setting up the containers for use the top and bottom flaps are locked together by hooked tongues inserted into suitable slits. Pressure exerted from within the container serves to hold lock securely.

A collapsible mailing carton was also devised which holds six of the individual containers or sufficient samples for three fields, in-

[1]Contribution from the North Carolina Department of Agriculture, Raleigh, N. C. Also delivered before the chemistry group of the American Association for the Advancement of Science, Philadelphia, Pa., December 28, 1940. Received for publication February 1, 1941.

[2]Senior Chemist and Director of Soil Testing, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 631.

cluding both topsoil and subsoil. This carton is made of corrugated cardboard, is self-addressed, and is very strong.

Thousands of both kinds of containers have been used very satisfactorily. They are relatively inexpensive when purchased in large lots, and being collapsible they require small storage space, are

FIG. 1.—Soil sample containers and shipping cartons, both folded and set up.

easily mailed, and permit systematizing laboratory equipment. They are put out by the department and most all samples come in them. Their availability has practically eliminated the use of irregular and questionable ones. The time consumed in handling containers in this laboratory has been reduced 60 to 70% by adopting this uniform type.

Blanks are sent out with the sample containers, these to be re-

turned with samples, giving a brief history of the fields as to past crops, fertilization, and proposed crops.

For analyses three samples are taken from each specimen of soil, these to be used for determining, respectively, the organic matter, the pH value, and the several plant food elements.

ORGANIC MATTER

The purpose of the organic matter analysis is to determine that which is easily oxidizable since it is considered to have a relationship to that which will decompose in the soil in a relatively short time. This consideration, in addition to its usual significance, is of vital importance in qualifying land for such crops as tobacco and peanuts.

A modification of Schollenberger's method (4) is followed.[4] In principle it is an oxidation process, sodium dichromate being used as the oxidizing agent. Sulfuric acid is added to produce the proper heat so as to facilitate oxidation. An excess of oxidizing solution is used for each sample, the unspent difference then being back-titrated by means of ferrous ammonium sulfate solution, with orthophenanthroline as an indicator.

This determination renders a fume hood essential because of the evolution of noxious fumes. Such a hood (Figs. 2 and 3) of conventional design, with forced draft, is used, but with the addition of an opening in one end for the introduction of trays containing sample flasks (250 ml, wide-mouth Erlenmeyers.)

Reagents are added to samples both outside and inside the hood, the latter addition producing the fumes. All manipulation is from the outside.

The trays with slat bottoms for ventilation and having a capacity of 36 flasks (four rows of nine each), are progressively moved along slides into the hood as reagents are added.

For adding dichromate solution, four self-leveling, 25-ml capacity pipettes are suitably mounted outside the hood above the end opening, permitting delivery to flasks by offset tips. They are fed by a single siphon tube from an overhead 5-gallon supply bottle.

For adding sulfuric acid, four pipettes (all glass, self-leveling, 25-ml capacity) are mounted inside the hood and spaced to match positions of flasks in the trays. The self-leveling feature, a departure from the conventional automatic pipette, is effected by a reversed "U" capillary overflow tip of bore just sufficient to allow breathing, but small enough to insure sucking back all contained acid when pipette is discharged, thus assuring satisfactory accuracy. This capillary feature also prevents excess overflow of acid. Overflow is taken care of by a glass manifold leading to a collecting bottle.

The siphon tubes for these pipettes are individual but feed from a common overhead acid supply. For adjustability, they have spherical ground joints close to the vertical upper limits, and for safety, a vertically affixed stopcock in the horizontal extension leading over to a supply bottle.

[4]Also unpublished data from R. P. Thomas, Maryland Agricultural Experiment Station, College Park, Md.

Delivery cocks, since they are mounted inside the hood, have flexible joint, metal, snap-on extensions (Fig. 3) to permit outside manipulation and are held to position by springs to avoid leakage. These

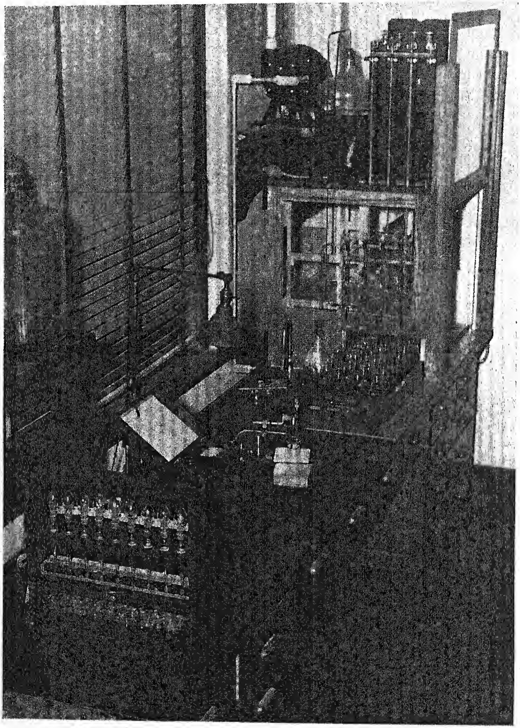

FIG. 2.—Equipment for pH and organic matter determinations.

extension assemblies can be disassembled by a single turn of a couple of screws. Lead pans safeguard all possible dripping.

The all-glass pipette and siphon assemblies are mounted in rubber to avoid strain and are protected by a metal grill.

The necessary water for working dilution is added by siphon inside the hood after oxidation is complete. Volume is controlled by marks on the flasks.

The interior of the hood contains a rack for holding two trays

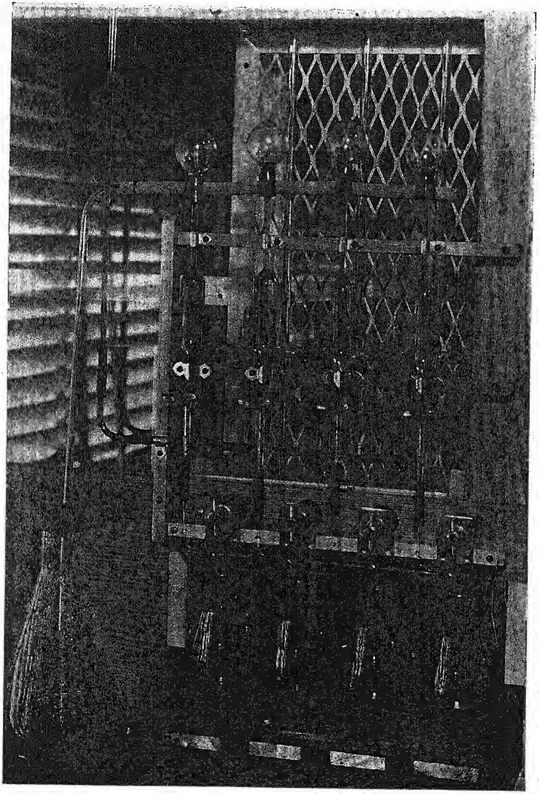

FIG. 3.—Detail of pipette assemblies for dispensing dichromate and sulfuric acid.

with space for a third on the slides. The draft of the hood in conjunction with slat-bottom trays expedites cooling of processed samples.

Processing in this determination is greatly facilitated. Eight flasks may be worked simultaneously without individual handling. The tedium and possible error of measuring and reading is eliminated, noxious fumes are completely controlled, and at least a minimum of 75% saving in time is effected.

SOIL ACIDITY

Soil acidity of pH value is determined by the glass electrode method. The industrial model, Beckman pH meter is used since it eliminates switch-button tapping and balancing, is not subject to polarization of electrodes, and reads directly in pH units.

Samples are contained in 25-ml beakers to which is added 12 ml of water. Here the handling of single beakers and the measuring of single portions are eliminated.

Trays holding 36 beakers (four rows of nine each) are used. Water is added from a battery of nine self-leveling, siphon-fed pipettes mounted as a unit (Fig. 2). A single operation fills the battery, while its reversal discharges it into the beakers, nine simultaneously. The tray is then slid into new position for continuation.

The pipettes differ from the conventional in having no glass stopcocks. Filling is from a manifold, through rubber tubes and glass capillaries, the latter being the side-arms of the pipettes, the retaining action of which effect suitably accurate measuring. Discharge is through blunt ends with small-bore orifices, then through short rubber tubes and glass tips. The cutoff is by pinchcock effect. Accuracy is effected here by pressure of the rubber tubes against blunt ends of the outlets. The limiting factor is the rapidity with which water can flow into and out of the pipettes.

For the measuring of pH, a ring stand (Fig. 4) adjacent to the meter is used on which are mounted glass electrodes, hinged supporting shelf, automatic stirrer and washer, and waste pan. A beaker is lifted into place on the fixed glass electrodes, the shelf swung into position to support it, this automatically switching on the stirring motor. The meter button is held down and reading taken. Upon removal of the beaker, a foot pedal is pressed to actuate siphon-fed, fixed jets which wash the electrodes. Waste is taken care of by a receiving pan with copper mesh cover to control spattering and a drain tube to the sewer.

Facility of operation, elimination of tedium, and conservation of time (at least 70 to 80%) are effected.

PLANT FOOD ELEMENTS

The methods employed for the determination of plant food elements are largely colorimetric and turbidimetric, soil extracts being used.

Eight different tests ordinarily are made, namely, calcium, magnesium, manganese, ferric iron, nitrate nitrogen, phosphorus, potas-

sium, and aluminum. Further tests such as sulfate, chloride, sodium, etc., are made upon problem soils when deemed necessary.

Extraction is accomplished by the use of a well-buffered perchloric acid (2) solution, approximately 0.6 N in titratable acidity and a pH

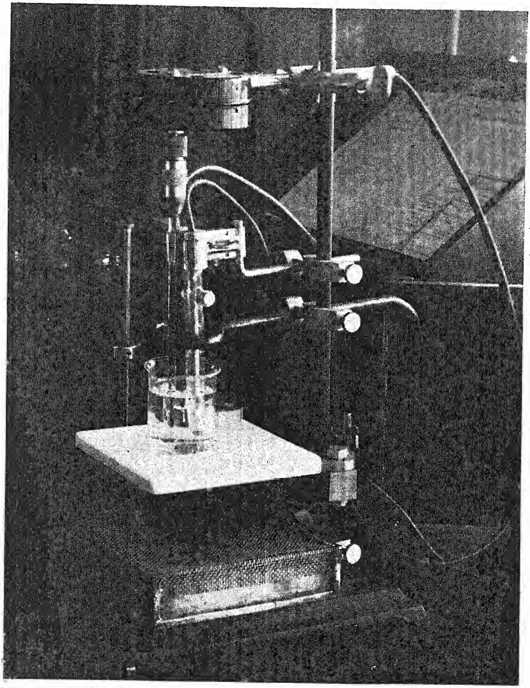

Fig. 4.—Detail of assembly for pH determination, showing mounting of stirrer, automatic switch, glass electrodes, washing jets, and waste pan.

of 2.0. Extraction is carried out in a 50-ml funnel which has a number o fritted glass disc filter.[5] A rubber policeman is placed on the stem end of the funnel to retain the solution during the extraction period.

[5]See footnote 4.

The solution and soil are put into the funnel and allowed to stand in contact for 20 minutes. The policeman is then removed and the extract upon which the tests are made passes through into a 50-ml Erlenmeyer flask.

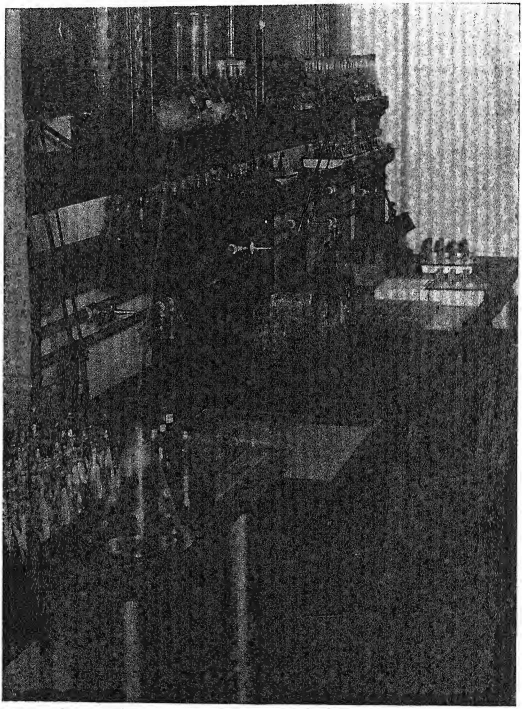

FIG. 5.—Table for plant-food elements determination.

For carrying out determinations with the extracts a special chemistry desk is provided (Fig. 5). In general design it is conventional, being equipped with reagent shelves, water, gas, and electricity, two 5-inch oval lead sinks, rail drawers, and pedistal cabinets. It is 30

inches high and has four swinging seats with backs, pivoted to cabinet structure, knee room being provided. Seats can be swung under desk out of the way when not in use. Comfort as well as convenience is embodied in this design. Lighting is by adjustable fluorescent daylight lamps.

The addition of leaching solution to soil samples is by a battery of pipettes the same as that for the addition of water in pH determinations excepting necessary changes in volume and dimensions. The pipettes (battery of nine) are 10 ml volume. Leaching funnels in receiving flasks as described above are contained in trays (36 per tray with four rows of nine each).

Pyrex glass spot plates are used for the color and turbidity reactions (Fig. 5). These rest on plate glass underneath which is a cross-sectioned chart of heavy and light lines (5). Visibility of the intersecting lines through the color and turbidity developed in the spot plates functions in readings. Other conveniences, such as pipette racks, wire baskets, etc., complete this equipment.

Advantages of this set-up are facility in handling volume work and in cleaning glassware, and economy in labor and energy.

SUMMARY

Large scale soil testing where economy in time and labor and facility in handling are to be considered presents a number of problems, including suitable handling and transport of samples, large volume of work in limited seasons, prompt availability of analytical results, etc.

In order to meet such problems improved applications, equipment, and technics were developed.

These are characterized by applicability, mass handling and processing, and automatic measuring and control.

The time and labor necessary in processing for the analysis of pH or soil reaction, organic matter, and plant-food elements are reduced 70 to 80% and difficulties in packaging, transporting, and handling samples are practically eliminated. The overall gain establishes a greatly improved level of efficiency for the work.

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INOCULATION EXPERIMENTS WITH COVERED SMUT OF BARLEY[1]

R. W. Woodward and D. C. Tingey[2]

COVERED smut of barley, *Ustilago hordei* (Pers.) Kell. and Sw., is a common disease of some economic importance. The percentage of infection in commercial fields in Utah usually is light, but moderate or heavy infections sometimes occur. Varietal resistance studies have been conducted at the Utah Agricultural Experiment Station since 1932. Such low infections were obtained in the earlier investigations that an effort was made to find feasible methods for producing higher and more consistent infection. High infection is essential for studies of resistance or of the inheritance of resistance to the organism causing covered smut.

METHODS

The plantings were all made in the field in rows 1 foot apart and 5 feet long, or longer. The treatments were all replicated except in one factorial experiment.

The inoculation technic used in the early studies consisted in shaking a quantity of grain in an envelope with an excess of smut spores. Because of unsatisfactory results, other methods were investigated. In some cases seed was moistened, inoculated with spores, and placed in a moist chamber for a few days. Both unhulled and hulled seeds were inoculated. Hulls (glumes) were removed by hand, or by running the barley through a wheat smut dockage machine, or by the use of concentrated sulfuric acid.

Later, as experimental work progressed, two other methods of applying smut spores were tried, namely, the "spore suspension" and the "vacuum spore-suspension" methods. The former method is discussed by Tapke (7)[3] and consists in shaking the barley seed in water containing a suspension of spores. The suspension was made by thoroughly mixing 1 gram of powdered inoculum to 1,000 cc of water. Following the inoculation, the seed was incubated at least 24 hours at from 20 to 25° C in a saturated atmosphere. The vacuum spore-suspension method (5) consists of a similar mixture of spores and water to that described by Tapke. The mixture of seed and spores in suspension is connected with a suction pump, and, at intervals, the partial vacuum is broken and the air allowed to return, drawing the suspension into the cavities under the glumes formerly occupied by air.

In addition to methods of applying inoculum, other factors thought to influence the degree of infection which were studied included location, soil productivity, depth, date, and rate of seeding, seed and soil inoculation, and time and temperature of incubation and germination of seed following inoculation.

Inoculum used in these studies was collected at various localities in Utah.

[1]Contribution from the Department of Agronomy and Soils, Utah Agricultural Experiment Station, Logan, Utah, in cooperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Approved for publication by the Director of the Utah Agricultural Experiment Station, May 29, 1940. Received for publication February 5, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 641.

In the germination studies the seed was kept between moist blotting papers for 24 to 48 hours after incubation.

Incubation consisted of placing both vials and jars between moist blotter papers in covered tin boxes to insure a humid atmosphere.

All collections of inoculum used were germinated in fresh water and found to be from 85 to 95% viable.

EXPERIMENTAL RESULTS

INOCULATION BY DRY SPORE METHOD

In 1932, experiments were started to study the comparative resistance of different strains and varieties of barley to the organism, *Ustilago hordei* (Pers.) Kell. and Sw. In this study, 48 varieties were inoculated with each of four different smut collections. The material was sown in triplicate on the Central Experimental Farm at North Logan, Utah, but covered smut failed to develop.

In 1933, the experiment was repeated, using the same varieties and some additional ones, with inoculum of six collections of smut from different parts of the state but mostly obtained from the Trebi variety. Seed of a number of varieties was hulled before inoculation for comparison with unhulled seed. The hulling was done with a wheat smut dockage machine which left about 5% of the seed unhulled. Again the conditions apparently were not favorable for infection because 95 strains were smut free. Seven had only a trace of smut and 13 had a light infection, and none had more than 20% infection. The infection was too low to determine accurately whether the different collections of smut or the hulled or unhulled seeds behaved differently.

Covered smut was prevalent in the vicinity of Price, Utah, in 1932, and smut tests were conducted there in 1933. These consisted of (a) a test of the resistance of 115 varieties and strains inoculated with dry spores of the local smut, and (b) tests of seed treatments commonly recommended for control. At harvest no more than a trace of infection was found, and little or no smut was present in the county.

EFFECT ON SMUT INFECTION OF PLACING MOISTENED, INOCULATED SEED IN HUMID ATMOSPHERE PRIOR TO SEEDING

In 1933, an experiment was conducted at Logan to determine the effect on the percentage of smut infection of moistening inoculated seed and placing in a humid atmosphere for different intervals prior to seeding. The percentage of infection was low, as shown in Table 1. There appeared to be little difference in the collections, except that B-5 consistently gave a lower infection than any of the others. However, this difference did not appear in later studies.

There appeared to be no significant difference in smut percentage in the unhulled and hulled seeds, and the effects of placing the moistened inoculated seed in humid atmosphere were not consistent. In the unhulled seed a slight increase in percentage of infection resulted, whereas in the hulled seed the 4-day treatment seemed to reduce the percentage of infection.

TABLE 1.—*Percentage of infected Trebi barley plants inoculated with six different collections of covered smut after different treatments at Logan, Utah, in 1933.**

Smut collection	Unhulled: Dry	Unhulled: Moistened in germinator, days 0	2	4	Unhulled: Average	Hulled: Dry	Hulled: Moistened in germinator, days 0	2	4	Hulled: Average	Grand average
B-1	23	18	19	24	21	6	7	7	25	11	16
B-2	14	21	9	28	18	7	20	28	12	17	18
B-3	12	5	20	23	15	23	27	25	5	20	18
B-4	24	16	15	22	19	28	35	28	4	24	22
B-5	1	5	7	8	5	6	8	8	1	8	7
B-6	12	6	10	13	10	25	36	17	5	21	15
(Untreated)	6	10	8	4	7	4	12	2	3	5	6
Average	13	12	13	17	14	14	21	16	8	15	15

*Each figure represents an average percentage of three replications.

EFFECT OF HAND AND ACID HULLING ON SMUT INFECTION

In 1935, two varieties, Trebi (C. I. 936)[4] and Baker (C. I. 975), were used in a study to determine the effect of method of hulling on infection. Briggs (2), Johnson (6), and Aamodt and Johnson (1) reported increased infection in barley seed hulled with sulfuric acid.

Hand hulling consistently gave the highest percentage of infection (Table 2), but the stand and vigor of the plants were reduced seriously. The average number of culms per row for unhulled, acid-hulled, and hand-hulled seed was 111, 101, and 61, respectively. Date of

TABLE 2.—*Average percentage of smut infection based on head count in Trebi and Baker barley from seed unhulled, hulled by acid, and hulled by hand and then inoculated by the dry spore method with six collections of covered smut and seeded on five different dates at Logan, Utah, in 1935.**

Seed treatment	March 14: Trebi	March 14: Baker	March 25: Trebi	March 25: Baker	April 11: Trebi	April 11: Baker	April 19: Trebi	April 19: Baker	May 3: Trebi	May 3: Baker	Average, both varieties
Unhulled	1	1	3	3	1	4	3	4	3	4	3
Acid hulled	4	2	7	6	9	7	8	5	13	8	7
Hand hulled	3	3	15	16	20	17	30	23	31	27	18

*The data for the six collections were averaged since they appear to represent the same race.

[4]C. I. refers to accession number of the Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture.

seeding likewise produced small differences in smut infection. There apparently was no difference in the infection produced by the six smut collections or in the two varieties, so the data for all collections are combined in Table 2.

Faris (3) and Tapke (8) showed the existence of physiologic races of covered smut of barley and the latter showed that his races 5 and 6 have been found in Utah.

SPORE SUSPENSION METHOD OF INOCULATION

In 1936, the "spore suspension method" suggested by Tapke (7) was used. Eight varieties were inoculated with each of six different collections and one composite of smut spores and were seeded on different dates in duplicate. Five of the varieties showed no appreciable infection and three, Algerian (C. I. 1179), Trebi (C. I. 936), and Winter Club (C. I. 592), had infections up to a maximum of only 20%. There again appeared to be no difference in the smut collections and date of seeding seemed to produce only slight differences in infection (Table 3).

EFFECT OF CUTTING BACK CULMS ON SMUT DEVELOPMENT

It has been shown by Tapke (9, 10) that certain environmental and post-emergence factors may influence the infection of barley. An experiment in which the culms were cut close to the ground when the barley plants were about 8 to 10 inches high and beginning to "boot" gave nearly identical smut percentages for the cut and uncut plants. Average percentage infection for seven smut collections for three dates of seeding and for three varieties was 9.6 and 9.9, respectively, for the uncut and cut treatments.

VACUUM SPORE-SUSPENSION METHOD OF INOCULATION

The vacuum spore-suspension method of Haaring (5) was used in 1937. Using Haaring's method, a study was made to determine if germination and incubation of inoculated seed at different temperatures prior to planting influenced infection. Seedings were made on two soils of different fertility and at two depths. Trebi (C. I. 936), Winter Club (C. I. 592), and Ezond (C. I. 5064) were used in these studies. The treatments were arranged and planted as a factorial experiment. The data are shown in Table 4.

The percentage of infection for this season was much higher than in any of the previous tests. The barley sown on the soils of lower fertility showed a consistently higher infection than that sown on a fertile soil. Ezond was smutted less than were the other two varieties. Treatments of seed prior to planting, such as incubation, including temperature, period of time, and container used; germination, and depth of seeding, caused no appreciable differences in smut infection. Taylor and Zehner (11) found increased infection from a 3-inch as compared with a ½-inch depth of seeding. A much higher percentage of infection is obtained when based on plant instead of head count, as shown in Table 4.

TABLE 3.—*Percentage infection of Trebi, Winter Club, and Algerian barley inoculated with six collections of covered smut by the spore suspension method and shown on different dates at Logan, Utah, in 1936.**

Smut collection	Smut infection of varieties indicated when sown															Average
	March 20			April 11			April 18			April 25			May 4			
	Trebi	Winter Club	Algerian	Trebi	Winter Club	Algerian	Trebi	Winter Club	Algerian	Trebi	Winter Club	Algerian	Trebi	Winter Club	Algerian	
S-1	1	4	3	19	15	9	18	13	8	16	10	4	6	8	8	9
S-2	1	14	1	10	17	6	16	3	7	11	12	6	11	6	7	9
S-4	7	4	2	11	25	12	5	8	6	7	12	12	8	18	6	10
S-6	7	12	1	18	8	7	13	8	10	0	12	7	3	6	5	8
S-14	4	0	1	10	10	14	5	12	12	11	17	6	5	13	1	8
S-19	4	4	6	13	6	9	10	4	11	3	11	21	5	6	0	8
Composite	5	7	1	14	15	18	15	17	20	19	19	11	1	15	9	12
Average for variety	4	6	2	14	14	11	12	9	11	10	13	10	6	10	5	
Average for date	4			13			11			11			7			

*Average of two replications in percentage of heads infected.

TABLE 4.—*Effect of various factors on percentage of smut infection by the vacuum spore-suspension method at Logan, Utah, in 1937.**

Variety	Fertility level	Average percentage smut infection under treatment indicated										Average	Varietal average
		Incubation temperature		Period of germination		Depth of seeding		Incubation containers		Incubation period			
		20°	25°	0 hrs.	24 hrs.	1½ in.	3 in.	Vial	Jar	24 hrs.	48 hrs.		
Based on Head Count													
Trebi	High	35	35	32	38	38	32	35	35	35	35	35	39
	Medium	42	45	42	44	40	47	43	44	42	44	43	
Winter Club	High	30	30	29	31	31	29	29	31	20	29	30	32
	Medium	34	33	34	34	30	38	34	34	38	30	34	
Ezond	High	18	18	17	19	20	16	17	19	19	18	18	25
	Medium	33	33	32	33	26	39	31	34	34	31	33	
Average		32	32	31	33	31	33	31	33	33	31		
Based on Plant Count													
Trebi	High	82	82	79	85	82	82	81	84	80	84	8	85
	Medium	88	89	87	89	87	89	89	87	88	88	88	
Winter Club	High	76	79	75	80	78	77	77	78	77	78	77	81
	Medium	86	84	84	85	80	90	84	86	86	84	85	
Ezond	High	56	53	51	58	57	52	50	59	53	54	54	66
	Medium	79	77	84	72	74	81	81	75	78	78	78	
Average		78	77	77	78	76	78	77	78	77	78		

*Each percentage is an average of 24 rows involving all other treatments.

EFFECT OF SEED AND SOIL INOCULATION

A test was made in 1937 to determine the smut produced by inoculating the soil with smut spores in different dosages as compared with seed inoculation. Six varieties were sown in duplicate in soil inoculated with 1, 2, and 4 grams of spores per square foot. The average of the treatments (Table 5) shows that soil inoculation was much less effective than seed inoculation in producing covered smut of barley. Increased quantities of inoculum in the soil failed to give material increases in infection.

TABLE 5.—*Average percentage of smutted heads in six barley varieties sown in soil inoculated with varying amounts of inoculum compared with seed inoculation by the spore suspension method at Logan, Utah, in 1937.*

Treatment	Smutted heads in varieties indicated					Average of treatments
	Trebi	Ezond	C.I. 5289	Velvon	Atlas	
			Inoculum in soil			
1 gram per sq. ft.	1	3	0	0	0	1
2 grams per sq. ft.	4	3	0	0	0	1
4 grams per sq. ft.	3	4	0	0	0	1
			Seed Inoculation			
Tapke method	26	33	5	1	0	13

RATE OF APPLYING INOCULUM

No appreciable increase in infection resulted from applying larger quantities of inoculum to the seed by a heavier load of dry spores, or a more concentrated spore suspension, or by reinoculating seed by the spore suspension method after drying. The average infection from 22 treatments of ½, 2, and 4 grams of inoculum per 1,000 cc of water, was 37, 36, and 45%, respectively. The standard concentration is 1 gram of inoculum to 1,000 cc of water.

EFFECT OF EMERGENCE CONDITIONS ON SMUT INFECTION

A summary of the smut infections obtained in five seasons and from different dates of seeding is shown in Table 6. Infection was light in 1938 and moderate in 1936, although mean soil temperatures during pre-emergence were similar. In 1935 and 1939 the maximum infection resulted from a mean soil temperature during pre-emergence of 45° to 47° F, while in 1936 the maximum infection followed temperatures of 54° to 60° F.

Faris (4) concluded that under the conditions of his experiments rather high infection was obtainable over wide ranges of soil temperature and acidity and at moisture contents common at seeding time.

TABLE 6.—*Summary of smut infections on susceptible varieties in five seasons and from different dates of seeding and various methods of inoculation.*

Date seeded	Date emerged	Period from seeding to emergence, days	Mean soil temperature from seeding to emergence, °F	Precipitation from seeding to emergence, inches	Average smut infection in all susceptible varieties, %*
			1935		
March 14	April 8	25	39.4	1.12	2
March 25	April 13	19	42.5	1.40	9
April 11	April 22	11	51.4	0.48	10
April 19	April 29	10	46.9	0.60	12
May 3	May 12	9	46.0	0.14	13
May 21	May 26	5	68.0	0.11	3
			1936		
March 20	April 10	21	45.6	2.34	4
April 11	April 18	7	57.4	0	12
April 18	April 25	5	60.4	0.03	11
April 25	May 2	7	54.2	0.97	11
May 4	May 11	7	54.3	0.61	7
			1937		
April 21	May 1	11	45.0	0.81	26
			1938		
April 16	April 29	13	54.3	0.58	2
			1939		
April 8	April 17	9	45.5	0.03	12
April 14	April 20	6	45.9	0	11
April 18	April 26	8	53.4	0.72	9
April 21	April 28	7	55.4	0.72	1
April 27	May 2	5	59.0	0.28	1
May 1	May 6	5	55.0	0	1
May 6	May 12	6	57.0	0.77	0
May 13	May 18	5	61.2	0.60	1
May 17	May 22	5	54.8	0.45	0

*Percentages based on head counts.

INFECTION AT DIFFERENT STATIONS

The smut infection in Trebi barley at Moscow, Idaho; Tucson, Ariz.; and Logan, Utah, when inoculated with composite collections of smut by the spore suspension method, was 36.2, 35.5, and 26.1%, respectively. Corresponding infections in the Velvon variety were 0.5, 0.5, and 1.3%. The same composite collection was used at Logan and Tucson, while a different composite was used at Moscow.

VARIETAL RESISTANCE TO COVERED SMUT BASED ON DATA FOR YEARS HEREIN REPORTED

The primary purpose of these studies was to determine the relative resistance of commercial barley varieties in order to build up resistant hybrids and to study the genetics of resistance in known material.

Along with the special smut studies reported herein a number of varieties were inoculated each year and studied for their reaction to the covered smut organism.

The reaction of 39 varieties of barley to the covered smut organism is shown in Table 7. The varieties are listed in three groups, according to the maximum percentage of smut obtained in any experiment. A total of 16 varieties were completely free from smut infection in these experiments. Another group showed a trace to 8% infection, though seldom did a variety exceed one or more tests. The smut percentages in most cases were too low to determine varietal reaction with certainty. However, the varieties most commonly grown in Utah, including Winter Club and Trebi, are in the most susceptible group.

TABLE 7.—*Reaction of barley varieties and strains to Ustilago hordei over a period of years.*

Maximum smut infection observed in different varieties based on head count					
None		Trace to 8%		Above 20%	
C. I. No.	Variety	C. I. No.	Variety	C. I. No.	Variety
	Coast	5105	Wisconsin Barbless	936	Trebi
4108	Sacramento	6109	Velvon	592	Winter Club
4118	Atlas	5289	Composite cross selection	5317	Composite cross selection
5976	Union Beardless		Colo. 3190	5400	Composite cross selection
2792	Colsess	995	Scarab	975	Baker
707	Peru	1286	Hero		Trebi×Atlas (B4-96)
2777	Beldi Giant	3339	Rhodesia	1179	Algerian
3388	Carre 48	3403	Lyallpur	6279	Lico
3393	Bonfarik	4160–2	Unnamed	5064	Ezond
3590	Unnamed		Colo. 3063		
3915–2	Unnamed		Atlas×Vaughn (Moscow No. 6)		
4141–3	Unnamed	1311	Flynn		
5329	Composite cross selection	5317	Composite cross selection		
5334	Composite cross selection	1367	Vaughn		
5339	Composite cross selection				
5439	Composite cross selection				

Two F_2 hybrid families and their parental varieties were inoculated with the covered smut organism and sown in 1938, but the amount of smut present was too low to permit a genetic interpretation. In the Union Beardless × Winter Club cross, 33% of the F_3 rows, and in the Winter Club × Colorado 3063 cross, 12.2% of the rows showed some smut. Although satisfactory studies of the inheritance of resistance to the covered smut organism in barley are not possible when

infection is light, resistant strains probably can under such conditions be isolated by smut tests conducted over a period of years.

SUMMARY

The reaction of barley varieties to covered smut (*Ustilago hordei*) and factors influencing infection were investigated during 8 years. The inoculum used in these experiments showed viability of from 85 to 95%.

When inoculated with dry spores, barley seed hulled with a smut dockage machine had no greater infection than unhulled seed. Seed hulled by hand produced a poorer emergence but a higher percentage of infected plants among the survivors than did seed hulled with sulfuric acid or than did unhulled seed. Inoculation after hulling was a more laborious and less effective method than inoculation either by the spore suspension or vacuum spore-suspension methods. Cutting back barley culms in the early boot stage did not increase the amount of smut. Barley grown on a soil of moderately low productivity had a higher infection than that on fertile soil.

Depth of seeding, date of seeding, wetting of seed, and treatment of seed following inoculation produced variable results but showed little consistent influence on infection.

Soil inoculation gave very low smut infection.

There was no evidence of more than one race of smut in the collections studied, although inoculum was collected from widely scattered localities in Utah.

Increasing the spore load beyond the ordinary amount used, either as dry dust or in spore suspension, failed to give increased infection.

Infection varied greatly from year to year even when barley was sown under apparently similar soil conditions.

Barley varieties differed in their reaction to covered smut. Trebi and Winter Club, the common varieties in Utah, were among those most susceptible. Velvon, a comparatively new variety now widely grown in this area, is highly resistant.

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SEED PRODUCTION OF SMOOTH BROME GRASS AS INFLUENCED BY APPLICATIONS OF NITROGEN[1]

C. M. Harrison and W. N. Crawford[2]

CURRENT interest in the utilization of smooth brome grass, *Bromus inermis* Leyss., for forage purposes has created a demand for a supply of high-quality seed. Although farmers have shown that brome grass seed can be produced in Michigan, information on desirable cultural practices is lacking.

The experiment here reported was designed to study the response of brome grass during the first and second seed years to different quantities of nitrogen. In conjunction with the study, the yield and protein content of the forage at the time of seed harvest, the number of fertile and barren tillers, several panicle characteristics, and the quality of the seed produced were investigated.

In August, 1937, a field of moderately fertile, slightly acid, Brookston loam soil on the experiment station farm at East Lansing, Mich., was fertilized with 400 pounds per acre of 0–20–20 fertilizer. Brome grass seed was mixed with oats and the mixture planted in 28-inch rows with a grain drill set to sow 2 bushels of oats per acre. Approximately 2½ pounds of brome grass seed were planted per acre.

1938 EXPERIMENT

The experiment was designed so that 0, 100, 250, 500, 750, and 1,000 pounds of ammonium sulfate (21%N) per acre were applied to each of triplicate 1/140-acre plots in mid-April, mid-May, and mid-June. The field was divided into three areas and each area was further divided into three blocks. The six rates of application were randomized within each block. This gave a 3 (replications) $\times$ 3 (dates of application) $\times$ 6 (treatments) layout. All of the experimental results were subjected to analysis of variance, and comparisons were made with reference to the average of the nine control plots which received no treatment.

Fig. 1 shows the actual and normal rainfall by months from June 1937 to July 1939.

The applications of ammonium sulfate were broadcast between the rows. One foot at each end and the outside rows of the plots were cut prior to seed harvest, the ultimate plots consisting of four 20-foot rows.

The seed was harvested by stripping the seed from the panicles August 20, dried 30 days at room temperature, and then threshed. The percentage purity was based upon a random three-gram sample of the threshed seed and the seed yield data were calculated to a pure seed basis.

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[2]Research Associate in Farm Crops and former graduate fellow in Farm Crops, respectively.

Immediately after the seed was harvested, the remaining forage was mowed and the green weight taken. A representative sample was dried four days at 60°C for dry matter determination and protein analyses.[3] Since the leaves of brome grass remain green when the seed is mature, the material left after seed harvest has definite hay or pasture value.

Applications of nitrogen were influential in increasing the vegetative growth previous to seed harvest (Table 1). The April treatments were least effective in stimulating vegetative growth, while the plots treated in May gave the highest yields of forage. A 1,000-pound application of ammonium sulfate in April did not significantly increase the forage yield when compared with a 250-pound application in either May or June.

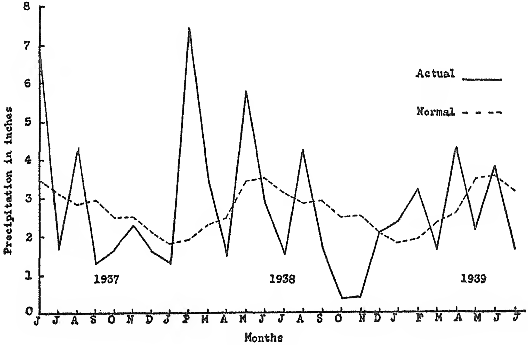

FIG. 1.—Monthly total precipitation from June, 1937, to July, 1939

The ratios of increase in seed production to the increase in forage production show that applications of ammonium sulfate in April, with the exception of the 100-pound rate, tended to stimulate seed production relatively more than forage production. Seed yield was similarly favored by the 100-, 250-, and 500-pound rates of application in May, whereas 750 and 1,000 pounds of ammonium sulfate applied in May favored vegetative growth. Applications of nitrogen in June produced marked increases in vegetative growth but had little influence on the seed yields.

While all of the ammonium sulfate treatments were associated with increased percentages of protein in the forage at the time of seed harvest, the June applications were most effective, especially on those plots where the rates of application exceeded 500 pounds

[3]The protein analyses were made by the Section of Chemistry of the Michigan Experiment Station.

per acre. Applications in April were least effective in increasing the protein content of the forage at the time of seed harvest.

TABLE 1.—*Data from 1938, showing yield of seed, yield of forage, ratio of increase in seed to increase in forage, and percentage of protein in the forage, averages of the three replications.*

Rate of application of ammonium sulfate, lbs. per acre	Seed yield, lbs. per acre	Forage yield, lbs. per acre	Ratio of % increase in seed to % increase in forage*	Protein, oven-dry forage, %†
		Control		
No treatment.........	50	989	—	9.23
		April 15, 1938		
100................	60	1,119	0.90	—
250................	64	1,106	2.25	9.49
500................	123	1,738	1.93	9.75
750................	109	1,713	1.62	—
1,000................	139	2,378	1.27	10.16
		May 16, 1938		
100................	130	1,666	2.35	—
250................	134	2,116	1.48	10.62
500................	157	2,679	1.85	9.55
750................	93	2,835	0.46	—
1,000................	107	3,465	0.46	12.79
		June 15, 1938		
100................	54	1,463	0.17	—
250................	55	1,801	0.12	10.02
500................	64	2,712	0.16	12.25
750................	41	2,245	—	—
1,000................	61	3,185	0.18	15.84
Difference $P=0.05$	99	791		
Required for significance $P=0.01$	135	1,078		

*Data were not statistically analyzed.
†Averages of duplicate determinations from two replications.

1939 EXPERIMENT

In order to study the influence of nitrogen on brome grass which was in the second seed year, a new set of plots were established in 1939 on an adjacent area in the same field. The plot design and rates of application were identical with the 1938 experiment.

SEED AND FORAGE YIELD

On July 20, a month earlier than in 1938, the mature seed was hand stripped from the plots, dried 4 days at 100°F, and then threshed. The percentage purity, yield, and protein content of the forage were determined as in 1938.

Table 2 shows that the nitrogen applied in April or May produced marked increases in seed and forage yields and that there was a

general increase in forage yield as the rate of application increased. Applications in June had little influence on the seed or forage yields and these plots were not visibly different from the untreated plots.

TABLE 2.—*Data from 1939, showing yield of seed, yield of forage, ratio of increase in seed to increase in forage, and percentage protein, averages of the three replications.*

Rate of application of ammonium sulfate, lbs. per acre	Seed yield, lbs. per acre*	Forage yield, lbs. per acre*	Ratio of % increase in seed to % increase in forage yield†	Protein, in oven-dry forage, %†
		Control		
No treatment	356	2,175	—	5.09
		April 24, 1939		
100	436	2,607	1.10	4.04
250	523	2,917	1.38	—
500	789	3,594	1.86	6.56
750	663	3,951	1.05	—
1,000	742	4,207	1.16	8.50
		May 15, 1939		
100	406	2,140	—	4.87
250	564	2,614	2.90	—
500	596	2,807	2.31	7.00
750	656	3,400	1.50	—
1,000	537	3,447	0.88	10.25
		June 16, 1939		
100	327	2,060	—	4.21
250	484	2,490	2.57	—
500	364	2,434	0.17	6.06
750	455	2,677	1.22	—
1,000	472	2,737	1.27	6.23
Difference Required for significance $P=0.05$	157	890	—	—
Difference Required for significance $P=0.01$	214	1,330	—	—

*A highly significant, remainder-term, coefficient of correlation, $r=0.81$, was obtained between seed and forage yields.
†Data were not statistically analyzed.

Of all the treatments in 1939, the 500-pound application in April produced the greatest seed yield. It also gave the greatest increase in seed yield per pound of nitrogen applied. Seed yields resulting from the May applications were generally lower than the corresponding applications in April; and a decided decrease in seed yield was apparent on the plots receiving the 1,000-pound applications in May. Lodging was evident on all the plots treated with more than 500 pounds per acre of ammonium sulfate in April or May and may account for the decreased seed yields with the heaviest rates of application. There were no apparent differences in the time of seed maturity between the treated and the untreated plots.

The ratios of percentage increase in seed yield to percentage increase in forage yield (Table 2) indicate that nitrogen stimulated seed production comparatively more than forage yield.

On the plots treated in April or May there was an apparent positive relationship between the amount of nitrogen applied and the percentage of protein in the forage at the time of the seed harvest. Applications in June, at the time of heading, were least effective in increasing the percentage of protein in the forage.

TILLER PRODUCTION AND PANICLE CHARACTERISTICS

The average number of fertile and barren tillers within an 8-inch quadrat placed at four predesignated points in each plot was considered a representative sample. One panicle was selected at random from each placing of the quadrat to determine, just previous to seed harvest, the number of florets and spikelets per panicle.

Table 3 shows that, while nitrogen had no apparent influence on the number of fertile tillers, the number of barren tillers bore a

TABLE 3.—*Data from 1939, showing the number of fertile tillers and the number of barren tillers per 8 inches of row, the number of spikelets per panicle, the number of florets per spikelet, and the calculated total number of florets per 8 inches of row, averages of the three replications.*

Rate of application of ammonium sulfate, lbs. per acre	Number of fertile tillers per 8 inches of row	Number of barren tillers per 8 inches of row	Number of spikelets per panicle	Average number of florets per spikelet	Calculated number of florets per 8 inches of row
		Control			
No treatment	47	39	38	4.43	7,723
		April 24, 1939			
100	44	40	42	4.77	8,571
250	45	63	36	5.60	9,618
500	59	51	42	5.50	13,569
750	49	82	48	5.40	12,049
1,000	50	105	41	5.93	11,980
		May 15, 1939			
100	38	34	36	5.03	6,843
250	44	48	38	5.63	9,275
500	41	77	42	5.40	9,124
750	51	83	36	6.40	11,780
1,000	34	98	40	6.13	8,123
		June 16, 1939			
100	41	42	33	3.80	5,318
250	50	53	32	4.53	7,929
500	32	76	35	4.00	4,353
750	43	85	34	4.50	6,637
1,000	50	99	36	3.90	7,027
Difference Required for significance P=0.05	21	22	11	1.06	1,960
Difference Required for significance P=0.01	29	30	15	1.45	2,666

positive relationship to the amount applied, regardless of the date of application. There was a tendency for density of the stand, as measured by the total number of culms per 8 inches of row, to be increased over the control by every rate of application greater than 100 pounds per acre.

The number of spikelets per panicle did not vary widely between treatments. The average number of spikelets per panicle on the plots treated in April was slightly higher than the average of the controls, the average on the plots treated in May closely approximated the controls, and the average number of spikelets per panicle on the plots treated in June was slightly below that of the controls.

With the exception of the 100-pound May treatment, every rate of application of nitrogen in April or May increased the calculated number of florets per 8 inches of row over the controls. The greatest number of florets were produced on those plots receiving 500 pounds of ammonium sulfate in April. The plots treated in June in general, produced a slightly smaller total number of florets per 8 inches of row than were produced on the untreated plots.

SEED QUALITY

Five hundred seeds were counted at random for each lot of seed used for purity analysis and the weight per 1,000 seeds determined.

Table 4 shows that in this experiment every application of nitrogen produced weights per 1,000 seeds greater than those from the control plots. The various applications in each month responded similarly, but, in general, the June treatments were most effective in increasing the weight per 1,000 seeds. Applications of 100, 250, 500, 750, and 1,000 pounds of ammonium sulfate applied in June produced, respectively, 5, 7, 9, 13, and 11% increase in seed weight when compared to the control.

Nitrogen applied in April or May had little influence on the test weight per bushel of the seed produced. On the other hand, applications in June produced marked increases in the test weight of the seed. All of the applications in June greater than 100 pounds per acre were about equally effective in increasing the test weight per bushel.

RESIDUAL INFLUENCE OF THE 1938 TREATMENTS ON THE 1939 CROP

The plots which were treated in 1938 were maintained to study the residual influence of nitrogen applications upon the subsequent season's growth. These plots were kept free from weeds and no further treatment was applied in 1939.

The data showed that the plots which were treated with 750 and 1,000 pounds of ammonium sulfate per acre in June, 1938, were the only ones which produced seed yields in 1939 materially above the average yield from the untreated plots.

The yields of forage in 1939 were significantly increased by the applications in 1938 of 1,000 pounds in April, 750 and 1,000 pounds in May, and 500, 750, and 1,000 pounds in June.

Applications of ammonium sulfate in 1938 had no material influence on the weight per 1,000 seeds.

TABLE 4.—*Data from 1939, showing weight per 1,000 seeds, test weight per bushel, and the percentage purity of the seed, averages of three replications.*

Rate of application of ammonium sulfate, lbs. per acre	Weight per 1,000 seeds, grams	Test weight per bushel, lbs.	Purity, %
	Control		
No treatment	3.25	14.7	95.2
	April 24, 1939		
100	3.36	13.4	94.5
250	3.52	14.7	96.2
500	3.48	14.3	96.4
750	3.58	14.1	96.7
1,000	3.63	15.1	95.8
	May 15, 1939		
100	3.36	15.0	96.5
250	3.42	14.8	96.6
500	3.53	14.3	97.5
750	3.52	15.0	97.1
1,000	3.47	14.0	95.0
	June 16, 1939		
100	3.41	15.7	96.5
250	3.49	16.8	97.4
500	3.53	16.7	96.3
750	3.66	17.1	96.8
1,000	3.60	17.0	97.7
Difference $P=0.05$	0.12	1.2	1.8
Required for significance $P=0.01$	0.16	1.7	2.5

DISCUSSION

Ammonium sulfate when applied in mid-April or mid-May of 1938 to a field of smooth brome grass planted the previous August had a slightly more beneficial effect on the seed yield and a less beneficial effect on forage yield than did similar applications in mid-June. It is suggested that much of the stimulating effect of the nitrogen in the early treatments was dissipated in the drainage water, since the fertilizer was applied too early in the season for the seedling grass plants to take up or utilize much of the soluble nitrogen.

On the plots established in 1939, when the brome grass plants were in the second seed year, the plants had developed root systems extensive enough so that the nitrogen put on in April was taken up to a much greater extent than it was in 1938. Regardless of the date or rate of application of nitrogen in 1939, a close positive relationship existed between the seed and forage yields. (See footnote, Table 2.)

Seed production in grasses is a form of food storage and consequently does not take place until food materials are manufactured by the photosynthetic tissue, in excess of vegetative growth requirements. The data from this experiment indicate that the yield of seed depended upon the amount of chlorophyll-bearing tissue produced throughout the growing season. The nitrogen applications had little

influence on the number of fertile tillers, whereas it did result in marked increases in the number and size of the barren tillers. A comparison of the tiller counts with the forage yields indicates that size was more important than the total number of tillers in determining the yield of forage at the time of seed harvest. This relationship suggests that not only the carbohydrates manufactured by the increased area of green tissue on the seed-bearing culms, but also a portion of that manufactured in the barren stems was available for storage in the seed-producing culms. While it was generally true that the plots which received the heaviest applications of nitrogen produced the greatest amount of foliar tissue, they did not necessarily produce the greatest seed yields. Extreme lodging resulted from the rank vegetative growth on these plots, and this probably interfered with the normal development of seed.

The yield of seed bore a close positive relationship to the calculated number of florets which produced seed, so it was evident that the addition of nitrogen either directly or indirectly stimulated the development of florets. The plots receiving 500 pounds of ammonium sulfate in April produced the greatest number of florets per 8 inches of row, the greatest number of florets which produced seed, and the greatest seed yield.

The total number of florets per 8 inches of row on the plots treated in June was generally less than that on the untreated plots, while the seed yield, with one exception, was slightly higher. The June applications were made at heading time when normal food storage had begun. The applied nitrogen stimulated vegetativeness at the expense of reserve carbohydrates and resulted in a partial depletion of the carbohydrate food reserves. As a result, some of the florets which would have developed failed to do so because of this return to a vegetative condition of the plants. The increased weight per 1,000 seeds and the comparatively high test weight per bushel of seed obtained from the plots treated in June probably compensated for the decrease in the number of florets produced when compared to the controls.

From the study of the residual influence of ammonium sulfate on the succeeding season's growth, it was observed that only the heaviest rates of application in 1938 resulted in seed and forage yields in 1939 materially greater than the yields from the untreated plots. It is inferred that part of the fertilizer remained in the soil throughout the season, or was stored in the plants in the fall to become utilized after the inception of growth in 1939. The prolonged period of drought during the fall of 1938 (Fig. 1) favored such a condition.

SUMMARY

Three sets of plots of smooth brome grass were treated with ammonium sulfate at five different rates of application; one set in April, a second in May, and the third in June. The experiment was carried out during the first seed year and repeated on a new set of plots during the second seed year.

Nitrogen applied in April or May of the first seed year resulted in seed yields greater than the controls, whereas the same applications in

June did not consistently stimulate seed yields. In the second seed year, applications in April resulted in marked increases in seed yield when compared to the control. The May applications were generally not as effective as those in April, while applications in June resulted in seed yields only slightly greater than the control.

Lodging was evident with the highest rates of application of nitrogen in June in the first seed year and in April and May in the second seed year.

There were no apparent differences between the treated and the untreated plots in the time of maturity of the seed.

Forage production was stimulated most by the applications of nitrogen in May in the first seed year and by the April applications in the second seed year.

The number of fertile tillers and spikelets per panicle were only slightly influenced by the applications of nitrogen; whereas, the number of barren tillers and florets per spikelet were significantly increased. In both years of the experiment the protein analyses showed that the protein content of the forage at the time of seed harvest consistently increased as the rate of application of nitrogen increased. June was the most effective date of application in the first seed year; whereas, April was the most effective in the second seed year.

Only the heavy applications of nitrogen in April, May, or June in the first seed year were associated with increased seed or forage yields in the second seed year when no further treatment was applied.

SOIL AGGREGATION AND WATER PERCOLATION STUDY FROM A LIMITED AREA IN THE SALT RIVER VALLEY, ARIZONA[1]

B. IRA JUDD, H. HUNSAKER, AND MILTON GOLDMAN[2]

IN THE Salt River Valley of Arizona, as in many irrigated areas of the west, are found numerous "slick" or alkali spots. Water penetration on these spots is slow and in some cases practically nil.

The investigation herein reported was undertaken with soil from a field comprised of soils designated by the federal soil survey (2)[3] as Sunrise clay loam and Sunrise silty clay.

The purpose of this study was to determine if a correlation could be established between water percolation and percentage of aggregation for the particular soil in question. Two areas within 50 feet of each other were chosen as the sample plots in a field planted the previous year to alfalfa. On the productive area plant growth was vigorous (Fig. 1), while on the alkali plot (Fig. 2) there was no vegetative growth.

PROCEDURE

The samples were obtained by the method described by Judd and Weldon (3). Cylinder tubes of brass 3.867 inches in inside diameter and 6 inches long were used. The lower end of the cylinder was sharpened to facilitate its entrance into the soil. By placing a short board over the top of the cylinder and bearing down the cylinder was forced into the soil until the top of it was even with the surface of the soil. This leaves the soil in the cylinders undisturbed and permits tests that are comparable to natural conditions. Each cylinder was then excavated and the lower end of the soil column was cut off flush with the bottom of the cylinder. Lids were placed on the ends of the cylinders and the six cylinders taken into the laboratory for the percolation study.

The samples were taken in triplicate from the two respective areas at each sampling. A total of 58 samples or cylinders from each plot was taken. The procedure used for obtaining the percolation rate was as follows: The lids were removed from the ends of the brass cylinder and the bottom of the soil column was covered by filter paper, cheesecloth, and galvanized hardware cloth, successively. The cylinder was placed upright in a funnel (Fig. 3) which supported the hardware cloth in proper position. On top of the soil column were placed a filter paper and a disc of brass window-screen wire to prevent erosion of the soil when water was added. A band of automobile inner tube was placed around the top of the outside of the cylinder, leaving about 1 inch of rubber projecting above the brass to act as a reservoir to hold the water. Six funnels and cylinders were supported in a rack. Fastened to the top of the rack were two small iron pipes.

[1]Contribution from the Agriculture Department, Arizona State Teachers College, Tempe, Ariz. Received for publication February 8, 1941.

[2]Head, Agriculture Department, and undergraduate student assistants, respectively. Acknowledgment is made to Weymouth Pew for the drawing in Fig. 3.

[3]Figures in parenthesis refer to "Literature Cited", p. 656.

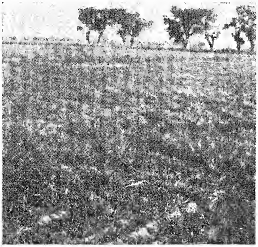

FIG. 1.—Nature of the plant growth on the productive area.

One of these was attached to a vacuum pump and the other to a supply of water. Tap water was used in the experiment.[4] By means of rubber connections and screw clamps, both inflow of water and suction could be regulated as desired. The apparatus maintained a thin sheet of water on the surface of the soil and thus maintained a small constant hydrostatic head.

Gallon buckets (graduated cylinders are recommended if it is desired to record volume of percolate at definite intervals) were placed under the funnels to receive the percolate. After an interval of 12 hours arbitrarily chosen, the volume of percolate was recorded. These results are shown in Table 1.

AGGREGATE ANALYSIS

After the percolation experiments were completed, the soil in the cylinders was used for the study of the state of aggregation. The cylinders of wet soil were placed in contact with dry soil for 24 hours to draw off the excess water by capillary action. The moist soil was then removed from the brass cylinders and screened through a sieve of four meshes per inch. This was done carefully in order to disturb the aggregates as little as possible. After the soil had been thoroughly mixed, three 100-gram samples were carefully weighed out. One of these was used to determine the moisture percentage; the second completely dispersed, all gravel, roots, etc., and inert material larger than 0.5 mm determined; and the third was used for determining the aggregate analysis.

The percentage of the soil mass larger than 0.5 mm was determined by the slaking method of Tiulin (5) as described by Rhoades (4). This consisted essentially of placing the 100-gram sample on the upper soil screen of a nest of three screens having 2-mm, 1-mm, and 0.5-mm openings, respectively. The nest was held in the hands of the operator

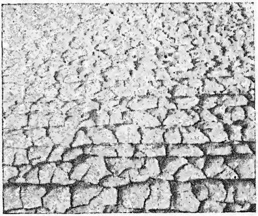

FIG. 2.—Bare soil designated as an alkali spot. Photo taken 50 feet west of spot shown in Fig. 1.

[4]The salt content of the tap water was not considered as facilities were not available for studying its effect on the base status and permeability.

TABLE 1.—*Water percolation and soil aggregation in productive and alkali areas, when the percolation from alkali area was zero.*

Productive area		Aggregation in alkali area, %
Percolation, cc per 12 hrs.	Aggregation, %	
340	18.7	1.7
690	13.2	1.7
465	17.1	1.3
1,250	22.9	3.7
255	17.7	1.6
520	13.3	3.2
552	13.0	4.8
432	20.8	3.7
1,315	18.4	2.1
548	16.3	2.0
1,350	9.2	4.0
2,289	13.8	2.1
658	14.6	1.8
260	6.4	3.1
258	6.8	4.1
278	6.3	4.1
870	22.1	2.9
10	23.3	2.8
245	27.4	3.2
1,090	9.5	0.5
1,070	9.9	3.6
130	9.9	3.6
730	5.3	3.0
122	2.9	4.3
390	3.5	3.9
3,508	12.3	2.5
2,600	13.9	2.1
2,140	11.7	2.0
3,620	19.8	3.5
2,990	12.3	2.5
710	15.8	1.8
1,780	17.6	4.9
1,070	17.7	1.0
3,740	19.7	4.2
1,570	14.7	4.7
2,250	16.9	1.1
1,040	17.2	2.4
1,185	15.8	1.9
1,720	13.5	2.3
200	9.7	2.4
705	14.3	2.4
1,440	17.2	2.7
1,720	23.3	3.3
1,530	13.8	3.4
515	14.0	3.2
2,340	16.1	1.8
640	10.1	4.6
1,005	17.2	2.7
940	16.5	4.1
1,030	18.0	3.3
1,025	20.6	3.5
1,955	18.9	2.3
1,360	20.5	4.1
1,500	22.8	2.8

TABLE 1.—*Concluded.*

Productive area		Aggregation in alkali area, %
Percolation, cc per 12 hrs.	Aggregation, %	
2,136	26.2	1.5
1,695	25.1	1.5
2,275	21.8	2.8
1,200	16.0	1.1
Total.....71,250	903.3	163.0
Av....... 1,228.5	15.6	2.8

and immersed in a vessel of water in such a manner that all the soil was covered. Then the nest was raised and allowed to drain for a few seconds before the process was repeated. Each sample was immersed 30 times, at the end of which time the aggregates on each screen were carefully transferred to a container and oven dried. For the final tabulation the oven-dried inert material was subtracted from the corresponding aggregation sample. By taking into consideration the moisture percentage, the percentage of aggregates greater than 0.5 mm was computed on an oven-dry basis.

Table 1 lists the percolation and percentages of aggregation for the productive and alkali areas. It will be noted that no percolate was obtained from the alkali spot which showed extreme impermeability. The soil samples were taken in such a manner to avoid including the surface cracks which were so prevalent.

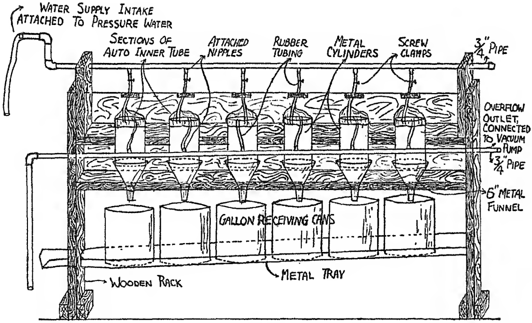

FIG. 3.—Apparatus for measuring percolation of water through undisturbed soil columns.

DISCUSSION

The correlation coefficient was determined between the percentage of aggregation and amount of percolate from the productive area. It was thought that a definite positive correlation would be obtained. However, this was not the case. It was found that r closely approached the smallest value of significance at the 5% level of significance since it was .253, while the smallest value of r to be significant according to Fisher (1) is .259.

On the basis of direct comparison of the results between the two areas an interesting feature is noted. Considerable aggregation and infiltration were found in the productive area as compared to the unproductive one. In the former case the aggregation was 15.6% while in the latter one it was only 2.8%. The average percolation was 1,228.5 cc over the 12-hour period for the productive area compared with no percolation from the soil of the alkali spot. This averaged 102.4 cc per hour, or approximately 0.51 inch per hour.

Without doubt the lower aggregation percentage results in a smaller percentage of soil air and less activity by the useful microorganisms of the soil.

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BORON DEFICIENCY RELATIONS IN SUGAR BEETS GROWN FOR SEED IN OREGON[1]

Golden L. Stoker and Bion Tolman[2]

Boron deficiency in sugar beets grown for sugar was described by Brandenburg (1)[3] in Europe in 1931, and since that date the deficiency has been recognized and described in many localities. Kotila and Coons (3) were the first to connect certain root troubles observed in Michigan and Ohio with boron deficiency. Berger and Truog (2) have pointed out the desirability of using plants with a high boron requirement to test for boron deficiency in soils and the sugar beet is one of the plants that has been commonly used. Observations reported in this paper indicate that the sensitivity of the beet plant as a boron-deficiency indicator can be heightened by selecting the growing season that will provide the possibility of observations either during periods of freezing temperature or during the period of seedstalk development.

HISTORY OF SUGAR BEET SEED GROWING IN OREGON

The development of sugar beet seed production in Oregon, leading to the discovery of some new aspects of boron deficiency, has taken place in the past five years. Exploratory investigations of sugar beet seed growing in Oregon were started in the fall of 1936 by George T. Scott, Manager of the West Coast Beet Seed Company, in cooperation with the Oregon Experiment Station. In that fall, at the request of Mr. Scott, the Division of Sugar Plant Investigations sent F. C. Reimer, Superintendent of the Southern Branch Experiment station at Talent, Ore., seed of several varieties, some of which were so low in bolting tendency that satisfactory reproduction by the method of overwintering in the field (4) had been impossible in the previously established seed-growing areas.

During the summer of 1937 these lots all flowered uniformly during the same period and produced seed of satisfactory quality. This was the first successful demonstration of sugar beet seed growing in the Pacific Northwest by the overwintering method. Tests were expanded the following fall to include a field planting at Corvallis, Ore., in cooperation with the Farm Crops Division of the Oregon Experiment Station and under the direction of G. R. Hyslop. Following these trials the sugar beet seed industry in southwestern and western Oregon expanded rapidly. More than 500 acres were planted in the fall of 1939 and in 1940, 1,742 acres were planted in Oregon with

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[1]Contribution from West Coast Beet Seed Company, Salem, Ore., and Salt Lake City Field Laboratory, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication April 8, 1941.

[2]Agronomist, West Coast Beet Seed Company, and Assistant Agronomist, U. S. Dept. of Agriculture, respectively. The authors are indebted to Dr. Eubanks Carsner, Senior Pathologist, Div. of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture, for help given in the way of field observations and suggestions in the preparation of the manuscript.

[3]Figures in parenthesis refer to "Literature Cited", p. 665.

additional plantings in northern California and Washington totalling 884 acres.

CLIMATIC AND SOIL CONDITIONS

The climate in the Willamette Valley is characterized by a wet and a dry season. The wet season, usually beginning in October, continues to the latter part of April or the middle of May, the wettest months being November, December, and January. Very little rain is expected between the middle of June and the first of September. July and August are normally very dry, the average precipitation for these two months being only about 3/4 inch. Inasmuch as most of the precipitation occurs during the winter months, supplemental irrigation is necessary in the production of sugar beet seed. On both experimental plots sufficient overhead irrigation was applied so that at no time was moisture a limiting factor in plant growth and development.

The average frost-free season, as given by the U. S. Weather Bureau Station at Albany, is about 212 days. However, sugar beets overwintered in the field are much more winter hardy than a great many other crops. Some frost damage can be seen on the beet foliage during the coldest part of the winter, but the beets in general remain green and some new growth is evident during most of the winter months unless some other unfavorable condition, such as a nutrient deficiency, checks the growth. The spring and summer months are cooler than in interior valleys.

Soils of the Willamette, Chehalis, and Newberg series are the best soils in the Willamette Valley for general farm crops and the acreage devoted to production of sugar beet seed in that area has been almost exclusively restricted to soils of these three series. Soils of the Willamette series occupy the older parts of the valley and are the most productive of the old valley-fill soils. Soils of the Chehalis and Newberg series are recent-alluvial river bottom soils, the Chehalis soils generally being found on the higher bottom lands.

Inasmuch as all of these soils have adequate surface drainage and good under-drainage, they are subject to the leaching which normally occurs in areas of heavy precipitation.

OBSERVATIONS ON SEEDSTALK INJURY

The injury dealt with in this paper was noted for the first time on sugar beet seedstalks in the Willamette Valley in Oregon in the summer of 1938, when George T. Scott and F. V. Owen and Charles Price[4] visited the planting at Corvallis, Ore. At this time Dr. Owen and Mr. Price expressed the opinion that the injury might be due to boron deficiency and comment was made regarding the similarity of the injury to boron deficiency symptoms which F. G. Larmer and L. M. Pultz[5] of the Salt Lake City, Utah, laboratory of the

[4]Geneticist and Associate Agronomist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture.

[5]Assistant Pathologist and formerly Associate Physiologist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Division of Sugar Plant Investigations had produced in sugar beet seedstalks in sand cultures and as reported in their 1932–33 annual reports.

The trouble was again and more widely observed, not only in the Willamette Valley, but also at Table Rock in southwestern Oregon in the summer of 1939. During this season several hypotheses as to the cause of the trouble were advanced on the basis of field observations. The first of these and one which received considerable support was that it might be the result of frost injury. This hypothesis did not hold when symptoms continued to develop both on new plants and on the partially recovered plants. Another suggestion was that it might be a virus disease carried by the spittle bug which was doing considerable injury in some fields. This hypothesis was ruled out when affected plants transplanted to fertile greenhouse soil[6] promptly recovered. The possibility that it was due to boron deficiency or some other soil deficiency was considered. In favor of this idea was the fact that work by Powers and Bouquet (5) had shown that table beets in this area sometimes show root canker due to boron deficiency, and the additional fact that the symptoms were most common and most severe in fields or portions of fields suffering from drouth.

On May 8, 1939, the senior author applied boron in water to a small area in an unirrigated commercial field near Canby, Ore., where the injury was rather severe. Water alone was similarly applied to an equal area. A slight improvement in the growth of the treated plants was noted on July 1.

RELATIONSHIP TO FREEZING INJURY

The diagnosis of the trouble was finally made when the results of two rather comprehensive fertilizer trials in Linn County and some supplemental greenhouse tests became available. One experimental plot located near Harrisburg was on soil of the Willamette series. The injury was more pronounced on this field. The other plot was located on soil of the Newberg series west of Jefferson. Included in each of these two field experiments were four plots to which boron was added and a like number without boron. On the experimental plot near Harrisburg some difference in rate of growth between beets on the boron and no-boron plots was evident during the fall growing season. However, none of the typical symptoms of boron deficiency, as previously described (1, 3), were observed. The first striking response to the boron treatment, and one which seems not to have been noted before, was seen at the Harrisburg plot on November 14, 1939. Before this date the coldest night of the season was November 10, when a minimum of 31°F was recorded at the Corvallis Weather Bureau Station. Observations at the Harrisburg plot on November 14 revealed that some of the plots were gray-green in color, making a sharp contrast to the normal green of the more vigorous plots. Closer examination showed that the difference in color was associated with a difference in susceptibility to frost injury. In all cases the leaves of

[6]Injured plants were transplanted in greenhouse soil at the Division of Sugar Plant Investigations Laboratory, Riverside, Calif., in the summer of 1939.

beets on plots which had received no boron were badly frosted, while leaves of beets growing on plots which had received boron showed only inconspicuous frost injury (Fig. 1). Plots which had received lime but no boron showed the most severe frost damage.

Fig. 1.—Contrast in size and condition of beets taken from the no-boron and boron plots of the experimental field near Harrisburg, Ore., the last week of January 1940. Much of the leaf damage evident on the boron-deficient beets was due to the increased frost injury which occurred on the no-boron plots. The beets on the right are from plots which received 30 pounds of borax per acre in August of 1939.

During the month of January, previously known symptoms of deficiency were noted in the areas where the frost injury was evident. Although all the beets did not manifest the same symptoms of deficiency, some developing leaf symptoms only, some suffering breakdown of the root tissue only, and others developing both symptoms, it was possible to follow rather clearly the development of secondary symptoms. The first abnormal conditions noted were a dwarfing and flattening of the foliage accompanied by the development of small, thickened, savoyed leaves which gave the foliage a rosette appearance. These plants soon developed brittle petioles and leaves, and many of the leaf blades had a granular appearance. The concave surface of

many leaf petioles first showed russeting and then a breakdown in the form of cross and linear checking. As the center leaves developed, many of them were blackened and as the winter season advanced some plants were completely devoid of leaves due to a breakdown of the tissue at the base of the older leaves. In many cases the terminal buds were killed so that later, multiple seed stocks developed from the side buds in the crown tissue. Many roots developed a darkened layer under the skin, followed by root cankers (Fig. 1). Frost injury was involved in the development of these symptoms.

SUPPLEMENTARY GREENHOUSE TRIALS

Following development of the above-mentioned deficiency symptoms in the field, some supplementary greenhouse trials were conducted, both in soil and sand cultures. The results of one of the tests is shown in Fig. 2. Both of the plants shown were taken from the Harrisburg plot the latter part of January. They had both received boron in the fall and at the time they were taken to the greenhouse they were in a vigorous growing condition. One of the plants was potted in soil taken from the plot from which the beets were obtained and which had received boron in the fall. The other plant was potted in soil obtained from one of the no-boron plots and where the beets were showing boron deficiency symptoms. The plant potted in soil supplied with boron grew normally, while the plant potted in soil to which no boron had been applied grew normally for a short time and then became stunted and later developed blackened areas on the upper part of the seedstalk. The blackening of the main seedstalk on the boron-deficient plant shown on the left in Fig. 2 can be seen in a closeup view shown in Fig. 3. The sand culture experiments[7] gave further evidence that the injury was due to boron deficiency.

DEFICIENCY SYMPTOMS ON SEEDSTALKS

In the field, with the resumption of spring growth, the obvious symptoms of boron deficiency temporarily disappeared. The reappearance of deficiency symptoms occurred during the period of rapid seedstalk elongation and continued during the entire period of seed development. The deficiency was first manifested by a dwarfing of the seedstalk accompanied by an unusually dark green color of the foliage and developing inflorescence. This was soon followed by a distortion and darkening of the upper part of the central seedstalk and the darkening and death of some or all of the lateral floral shoots. Often, affected plants partially recovered and the multiple second growth shoots formed a witches' broom type of inflorescence. Some affected plants were so severely dwarfed that they developed only short and unbranched seedstalks. Several of the above-described symptoms can be seen in Fig. 4. In any one field where this injury occurred it was possible to find plants with all stages of the above symptoms along with plants that apparently were developing norm-

[7]Sand culture experiments were conducted by Myron Stout, Assistant Physiologist, at the Salt Lake City, U. S. Sugar Plant Field Laboratory. The beets used were obtained from the Harrisburg plot.

ally. In at least one field there were areas where all of the plants exhibited some symptoms of boron deficiency.

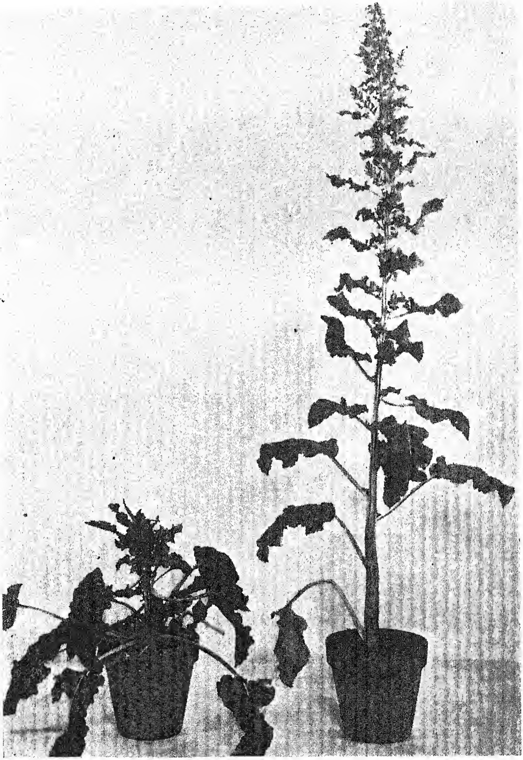

FIG. 2.—Contrast in the growth of plants in 12-inch pots planted in soil deficient in boron (left) and in soil to which borax had been added at the rate of 30 pounds per acre (right). Both plants were taken from boron-treated field plots near Harrisburg, Ore. The plant on left was potted in soil from plot without boron; the plant on right was potted in soil from boron-treated plot.

Symptoms of boron deficiency, similar to those described at Harrisburg, were also observed in the plots at the Jefferson field, but in this

FIG. 3.—Detail of the seedstalk injury which developed on the boron-deficient plant shown on the left in Fig. 2.

field the boron content of the soil was not so low as in the Harrisburg field. This was shown by the fact that the frost injury relationship developed at a later date and following periods of colder weather

than that of November 10. There were also fewer plants which developed the usual boron-deficiency symptoms.

The abundant occurrence of frost-injured leaves was also noted in many commercial fields, and this easily detected symptom served as a guide to fields or areas in fields where plants with more advanced symptoms could readily be found.

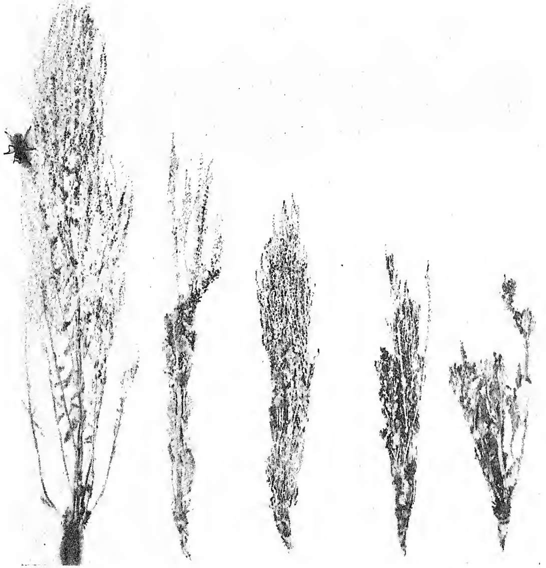

FIG. 4.—Contrast of four boron-deficient plants (right), with plant receiving boron (left). Note multiple seed-stalks developed from side crown buds, blackened seedstalks with dead terminal buds, and witches' broom type secondary growth developing after death of the terminal buds.

Subsequent to the completion of these studies the fact was discovered that Solunskaya (6), by means of sand cultures, had demonstrated boron-deficiency symptoms in sugar beet seedstalks. These experiments in Russia were conducted in 1932–33 and the results published in 1934.

BORON APPLICATIONS TO COMMERCIAL FIELDS

As a result of the discovery that boron deficiency in commercial fields was clearly manifested during the winter months by the low temperature relationships, borax was applied to a number of fields in the early spring of 1940. The fields so treated developed normally in the spring and did not develop boron deficiency symptoms on the seedstalks. Hereafter, borax at the rate of 25 to 35 pounds per acre will be included as a regular part of the fertilizer schedule to be followed in sugar-beet seed production in western Oregon.

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PRESENT KNOWLEDGE OF THE NUTRITIONAL VALUE OF GRASSLAND HERBAGE[1]

W. M. NEAL[2]

GRASSLAND herbage and browse are the natural feeds of the Herbivora. In the natural or wild state the grass-eaters ranged far and wide, making rather systematic migrations during the course of the seasons. Requirements of these migratory animals from the nutritional standpoint were for growth, maintanence, reproduction, and sufficient milk production for the rearing of the young. These requirements were met by the native forage grazed from many soils.

With the domestication of livestock, followed by breeding and selection for high productivity, and the restraint of such livestock in fenced pastures of limited botanical composition oftentimes growing on soils containing too little of some of the plant nutrients, the modern problems of inadequate nutrition of livestock have come to the fore. Methods utilized to overcome inadequacy have included the use of supplementary feeds and mineral mixtures. The selection and production of grassland herbage of required intrinsic nutritional value should obviate the necessity for the use of a part of the present supplementary materials and permit the development of an agriculture more in keeping with the principles of conservation.

NUTRIENTS SUPPLIED BY HERBAGE

A ration, if optimum, contains all of the compounds necessary for the physiological well-being of the animal and its production of growth, milk, wool, etc. They must be present in satisfactory ratio and not diluted with undigestible residue to the point where consumption of sufficient feed is impossible. A grouping of these essential compounds may be made under the headings of protein, energy, minerals, and specific organic compounds.

The occurrence of at least 22 amino acids in various proteins has been established. The indispensability of 10 of these has been shown for the rat. Specific amino acid deficiencies have never been developed in cattle, due to the difficulty of compounding suitable rations and the probability of the synthesis of amino acids by microorganisms in the alimentary tract. The ability of urea to supply a part of the protein requirement of cattle may be construed as evidence for such synthesis. The recommendation for a diversity of protein sources in livestock rations for insurance of protein quality is based on results with other species of animals. However, quantitative requirements for crude protein are well established.

Energy is not derived from any specific group of compounds. Compounds capable of supplying energy include, among others, sugars, starch, organic acids, the complex polysaccharides, fats, and

[1]Contribution from the Department of Animal Industry, Florida Agricultural Experiment Station, Gainesville, Fla. Also presented before the Southeastern Grassland Conference, Tifton, Ga., July 23–26, 1940. Received for publication December 12, 1940.

[2]Associate Professor.

proteins. The availability of energy from some of the polysaccharides is dependent on fermentations by microorganisms. Grassland herbage is lower in its content of sugars and starches, which constitute the readily available energy, than the carbonaceous concentrates.

Investigation by Maynard, *et al.* (5, 6)[3] are indicative of a minimum fat level for dairy rations. The extraction of the fat, followed by its replacement with an isodynamic amount of starch, resulted in a decreased milk yield without any noticeable effect on fat percentage. Contrary to this finding is the successful lactation by cows on sole alfalfa hay rations containing less than 1% of fat (ether extract corrected for non-fatty constituents). It is possible that the extraction of the ration removed essential non-fat material, and the effect observed was not the effect of fat as such. Fat deficiency has not been recognized in animals restricted to grassland herbage.

Herbage is the principal source of minerals in the livestock ration. Ordinarily, the mineral composition of a plant is a reflection of the mineral composition of the soil. A lack of correlation between plant and animal mineral requirements is the fundamental cause of inadequate mineral nutrition of animals. If the plant required as much, or more, of any specific mineral element for its growth, as would provide adequately for any animal eating the plant, then, deficient feed crops could not be produced. Potassium is never deficient in natural rations, even though it is an essential element for animals, because plant growth will fail before the content of the element in the plant is reduced to inadequacy for the animal.

Sodium is rarely sufficient to meet the animal's needs because the plant requirement is so low that too little of the element finds its way into the plant to meet animal requirements. A level of sodium in the soil that would supply sufficient of this element for the animal's need via the plant would probably be toxic to the plant. Vegetation in salt marshes is an exception. Chlorine is in the same category as sodium.

Elements for animal welfare that may or may not be deficient in grassland herbage dependent largely on soil composition include calcium, phosphorus, copper, cobalt, and iodine. The proof of the essentiality of cobalt has vitiated the reliability of postulated iron deficiencies. Magnesium deficiency has been produced experimentally only. Natural zinc or manganese deficiencies have never been proved.

Sulfur has its greatest effect on the protein make-up of the herbage, and no deficiency of sulfur as sulfate has ever been shown. Selenium and arsenic have both been shown to affect the value of herbage by their occurrence in excess. Molybdenum might be included with this pair.

The biological method of assay is necessary for the determination of the requirements of cattle and sheep for many of the organic compounds. Successful raising of cattle or sheep on "purified rations" has not been accomplished. Many unknown compounds in unknown amounts are always included in cattle and sheep rations. It may be the presence of some of these unknown compounds in the natural

[3]Figures in parenthesis refer to "Literature Cited", p. 670.

rations that has prevented the normal raising of cattle and sheep on "purified" or "synthetic" rations. However, the requirement of cattle for many of the vitamins recognized to be necessary for other species of animals, particularly the rat, has been studied.

It has been shown that either vitamin A *per se*, or carotene, will meet the vitamin A requirement of cattle or sheep. Good green roughage, either fresh or cured, in medium amounts, will supplement a ration the other components of which are deficient in vitamin A activity. It would seem doubtful that animals consuming grassland herbage would develop avitaminosis A except where the plants had died and cured *in situ*, where the cut forage had been subjected to rainfall, or where the forage is so unpalatable that insignificant amounts would be consumed.

The lack of rations sufficiently low in individual members of the B complex, a negative requirement, synthesis by microorganisms in the intestinal tract or by the body itself, as the case may be, has prevented the proof of any dietary requirement of the B complex.

The raising of cattle on rations lacking in vitamin C has been construed as showing that cattle have no dietary requirement for this vitamin. Recently, Phillips and Lardy (4) have shown that injections of vitamin C have resulted in a return of potency in some sterile bulls while feeding the compound did not have a like effect. The presumed synthesis of ascorbic acid by the body has led some workers to classify it as a hormone. Further study is justified.

Grassland herbage has a very low content of vitamin D, while the same herbage when cut and exposed to the rays of the sun develops a considerable potency. Irradiation of the grazing animal's body by the sun aids in supplying the vitamin D requirement. Grazing animals under natural conditions have not been reported to show vitamin D deficiency.

Vitamin E, or α-tocopherol, occurs in most green plant tissue. The assay of many feedstuffs by Palmer, Nelson, and Gullickson (3) showed very few of them to have insignificant amounts. A requirement by cattle for vitamin E has not been proved.

It is well known that calves raised on milk supplemented with good quality roughage develop normally. Poor results when the fat of whole milk has been substituted with other oils may be interpreted as an indication of specific fatty acid requirements, or the requirement for some fat-soluble compound other than vitamins A and D. The ability of any particular constituent of grassland herbage to overcome symptoms encountered has not been investigated. Experiments have not permitted the identification of the constituent of roughage responsible for the improvement of milk and grain rations when roughage has been added to such rations. Johnson, Loosli, and Maynard (1) secured no benefit from the "grass juice factor" when they added it to purified rations for calves.

EVALUATION OF HERBAGE

If grassland herbage is to be evaluated, then methods for analysis and the determination of the use of this material in animal nutrition are necessary. Comparisons must be made between different forages

and samples of the same forage produced under various conditions. This is separate and apart from yield data or any of the physiological behaviorisms of herbage from the production standpoint.

The simplest and least reliable method is the chemical analysis of the material. Data derived from chemical analyses are of value in conjunction with other information. Within a species, a higher crude protein content will indicate a more than proportionately higher feed value. High contents of crude fiber will indicate low value because of its depressive action on digestion. Absolute amounts of minerals may show whether mineral deficiencies may be expected. This may be of no assistance where unknown deficiencies are encountered. Analyses for alkaloids and similar compounds may indicate that a forage is undesirable.

Digestion trials should follow analytical studies because data from such trials will show the available protein and total digestible nutrients. Forages of similar compositions may have vastly different digestibilities. Balance trials under certain conditions will show the net availability of some of the mineral constituents.

Even though two lots of forage apparently may have equivalent compositions and digestibilities, it is possible for them to be of unequal value to the animal. This is caused either by the inability of the responsible constituent to be determined analytically or by a lack of knowledge of the identity of the constituent. In this situation, the bio-assay is the best approach. The material is fed to the test animal in long-time experiments, symptoms are observed, and corrective measures instituted. Often times the symptoms will dictate the corrective measures and lead to analytical procedures whereby further bio-assays may be unnecessary. Symptoms may not indicate any of the known deficiencies, in which instance the problem is much more complex. The use of supplementary action of feeds may be the most practical solution to such problems.

FACTORS AFFECTING NUTRITIONAL VALUE OF HERBAGE

The species of herbage is recognized as important in determining feeding value. Legumes in general are higher in crude protein, calcium, and some other mineral elements than are the grasses. Also, the fertility of the soil and the use of fertilizers have certain known effects. For instance, the use of nitrogen will increase the protein content of the forage.

An unsolved problem, seemingly related to fertility, is the difference in the nutritive value of alfalfa hay, depending on point of production. Alfalfa hay has been used as the sole ration for dairy cows in the West with production at a level in keeping with the nutrients consumed, while certain alfalfa hay grown in Michigan has not supported lactation at a comparable level (2). The use of a very small amount of corn meal has corrected this seeming deficiency in the eastern alfalfa. Similar instances could be cited.

Without speculating as to the actual cause (the element or compound present in the western hay and not in the eastern, or *vice versa*), possible modes of action of differing soil fertility may be mentioned. The presence of one element in proper amount may be

necessary to enable the plant to utilize some other element, or its presence in excessive amounts may prevent the utilization of some element. Then, it is reasonable to presume that inorganic elements play an indirect role in animal nutrition by conditioning the synthesis of organic compounds necessary for the animal, a part of which are unidentified.

Whenever minerals are playing a direct role in the nutrition of the animal, their deficiency may be corrected by direct supplementation to the animal. Their use as fertilizer should be limited to an amount justified by response in yields. Under conditions where minerals play an indirect role, the problem is difficult of solution. Sulfur is the only mineral element known to be required in organic form. However, it is conceivable that the application of some other elements to the soil would have no effect on the yield of herbage, or the growth behavior of the individual plants, but would have effects on the plant in regard to unidentified organic constituents of unrecognized nutritional importance without being a component part of these compounds.

Agronomic attention is directed usually toward the improvement of yields of herbage, resistance to disease, plant adaptation, fertilizer requirements, management, etc., and more lately with the palatability of the herbage to the animal intended to consume it. A supplementation of this study by nutritionists studying the feed value of herbage produced under varying environment by different species of forage plants will aid the development of grassland agriculture.

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AGRONOMIC PRACTICES ON FARMS OF DAIRY HERD IMPROVEMENT ASSOCIATION MEMBERS, LORAIN COUNTY, OHIO[1]

EARL JONES[2]

IT HAS been said many times that education should begin at the level of the people who are being taught. If our teaching is to follow this principle, classroom and extension teachers of agronomy should have a fairly accurate picture of the practices followed on a large number of the farms of the state.

For the purpose of determining the agronomic practices of a definite group of farmers, the writer visited the farms of the members of the Dairy Herd Improvement Associations in Lorain County, Ohio, in June and July of 1939. The farmers were notified of the proposed visit ahead of time and almost 100% cooperation was given in securing the information desired.

In the dairy section of this county the soils are mainly Mahoning and Ellsworth, with almost level topography and poor natural drainage. The unlimed soils are acid and the use of fertilizers is necessary for satisfactory yields.

Sixty-three per cent of the farms visited were operated by the owner, 25% belonged to members of the operator's family, and 12% were owned by persons not members of the operator's family.

Only a limited amount of the agronomic data secured is given since it is not of universal interest. The following statements give an idea of the approach used in obtaining the information desired. The data given emphasize the forage crop program because we believe these are the most important crops on dairy farms in this section of Ohio.

LIMING OF ROTATION LAND

% of rotation land limed	% of the farms
None	15
None to 25	27
26 to 50	31
51 to 75	7
76 to 100	3
All	17

USE OF MANURE ON WHEAT TO HELP NEW SEEDINGS

	% of farms
No wheat manured	46
Some wheat manured	54
(not a universal practice on all these farms)	

[1]Contribution from the Department of Agronomy, Ohio State University, Columbus, Ohio. Also presented at the annual meeting of the Society held in Chicago, Ill., December 4 to 6, 1940. Received for publication December 16, 1940.

[2]Associate Professor of Agronomy (Extension).

All the farmers interviewed fertilized wheat, 83% fertilized corn, 87% fertilized oats, and 29% fertilized soybeans.

Forty-seven per cent of the farms had hay fields of alfalfa or alfalfa mixtures, even though the soil had poor natural drainage. The fields had, in all cases, been limed.

Soybeans were being grown on 87% of the farms and two-thirds of the operators planned to harvest part or all of this acreage for hay.

Seven per cent of these farmers had no permanent pasture. Twenty-six per cent had planted some Sudan grass for summer pasture and 35% were pasturing hay fields at the time of the visit. An electric fence was in use on 52% of these farms to help solve the pasture problem.

The permanent pasture on 81% of these farms was more or less unproductive. Fifty-seven per cent of these men had used manure on part of the permanent pasture acreage, 10% had limed some of the permanent pasture, and 3% had applied some superphosphate.

CONCLUSIONS

Only a few of the farmers visited were financially able to lime and fertilize some of their permanent pasture each year, to lime some of their rotation land, and to fertilize the rotation crops according to the latest recommendations. Most of them had to make a choice and do what they considered most important. It is a part of our duty to assist them in making the best choice.

A complete step-by-step program will be more useful to most of these farmers than an ideal program, in the judgment of the writer. Since the most important steps vary throughout the county, the proposition is not discussed in detail here.

The writer feels that all agronomy workers will profit by having exact knowledge concerning the practices followed by groups of farmers throughout the state. Time spent in visits of this kind will return large dividends.

NOTES

A PORTABLE SOYBEAN NURSERY THRESHER AND ITS OPERATION

INTEREST in the improvement of the soybean has given rise to a marked increase in the testing of introductions, selections, and varieties at numerous localities in the major producing areas. Threshing at outlying nurseries is a major problem since soybean plants are bulky and consequently costly to transport. Also, when handled excessively, the plants shatter badly, resulting in loss of considerable seed.

In order to overcome some of the inconveniences of this threshing problem, a portable nursery thresher was constructed at Lafayette, Ind., in 1938 and has been used very successfully through three seasons. This machine was designed after a thresher originally built by the junior author. Some of the features of the threshing and cleaning equipment of the nursery thresher used at the Indiana Agricultural Experiment Station and previously described by Cutler are incorporated.[1]

DESCRIPTION

Two views of the thresher, giving general details of construction and operation, are shown in Figs. 1 and 2. The frame is of wood, 6 feet long, 38 inches wide, and 42 inches high. The feed table is collapsible for ease in transporting and storing.

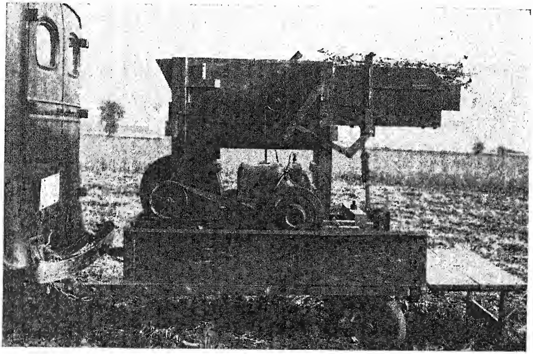

FIG. 1.—Portable nursery thresher viewed from motor side.

[1]CUTLER, G. H. Simplified equipment for rod row thresher. Jour. Amer. Soc. Agron., 24:585–587. 1932.

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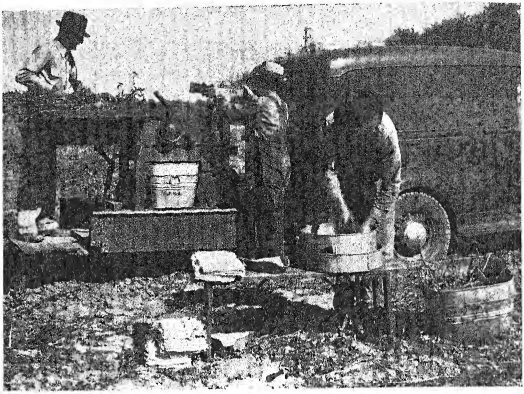

FIG. 2.—Portable nursery thresher in operation.

The cylinder, 8 inches in diameter and 12 inches long, is set with $\frac{5}{16}$ inch square teeth 1 inch apart. The concaves are mounted above the cylinder, thus making the threshing compartment self-cleaning. A cylinder speed of 550 r.p.m. has been found the most satisfactory. A hinged cover over the concaves makes the threshing mechanism quickly accessible for thorough cleaning. The cylinder, concaves, and mountings can be obtained commercially for about $42.

The thresher contains no straw racks or sieves, thus reducing the possibility of mixtures.

A paddle-wheel type of fan with an air chute located between the upright posts at the rear of the machine is used in cleaning the seed in the field. The fan and air chute were obtained from a discarded seed cleaner and cut to the appropriate size.

Power to drive the cylinder and fan is furnished by a 1½ h.p. gasoline motor mounted so that the cam-shaft pulley is directly under the cylinder pulley. The motor cam-shaft pulley is used to drive the cylinder when threshing and the crank shaft pulley operates the fan continuously for cleaning the seed. A flat belt for power transmission to the cylinder is made slack to permit stopping of the cylinder for cleaning, while the motor continues to run. An idler pulley serves as a clutch for this cylinder drive, and a hand brake is provided for rapidly stopping the cylinder.

A removable frame and screen guard over the motor and drive pulley and a removable guard over the brake pulley would provide greater safety in operation of the thresher.

This machine costs about $100 and weighs 300 pounds.

OPERATION

The thresher is securely bolted to the floor of a single wheel trailer that is easily pulled by a half-ton truck. Preparatory to threshing, the rear wheels of the truck and the wheel of the trailer are lowered a few inches into the ground to bring the thresher to a convenient working height. The trailer end-gate is hinged to the trailer floor and provided with folding legs so that when opened it makes a satisfactory platform on which the operator can stand to feed the machine.

The bundles of soybeans, which have been allowed to remain untied in the nursery row, are placed directly on the feed table and threshed, thus lessening the possibility of mixing and shattering from excessive handling. After each row is threshed the cylinder is stopped, the feed table cleaned, and the threshing mechanism inspected for lodged seed.

The straw and grain are discharged directly below the cylinder into a No. 41 square galvanized laundry tub that had been deepened by the addition of a 3½-inch band at the top to provide ample room for straw. The larger stems and stalks are removed from the tub by hand and the remaining straw and grain placed into a three-mesh, screened-bottom pan fitting over a six-mesh, screened-bottom pan into which the seed and finer chaff fall upon agitation. The chaff is then removed by holding the bottom pan over the air blast. A pair of goggles worn by the man feeding the machine would provide a safeguard against flying beans and particles of broken stems or pods.

Three operators have been able to thresh consistently 50 to 55 rod rows per hour under average conditions.

Blueprints of this thresher can be obtained from the authors. The authors express their appreciation to C. J. Goris, Lafayette, Ind., for ideas and suggestions made by him while constructing this machine.—A. H. Probst, *Junior Agronomist*, and J. L. Cartter, *Agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry and Bureau of Agricultural Chemistry and Engineering, U. S. Regional Soybean Industrial Products Laboratory, U. S. Dept. of Agriculture, and the Indiana Agricultural Experiment Station, Lafayette, Ind., cooperating.*

THE TOXICITY OF *INDIGOFERA ENDECAPHYLLA* JACQ. FOR RABBITS[1]

INDIGOFERA ENDECAPHYLLA Jacq. was introduced into the Florida Agricultural Experiment Station Forage Crop Nursery from Ceylon in 1925. The plant is a prostrate legume which makes second growth when cut and is a perennial as far north as Gainesville, Fla. The leaves are killed by the first frosts of the season, but growth is resumed from the prostrate stems in the spring.

[1]Contribution from the Departments of Animal Industry and Agronomy, Florida Agricultural Experiment Station, Gainesville, Fla., and the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Mundy[2] noted that this plant attains a height of 6 to 9 inches and was grazed by cattle and sheep while the fodder was eaten freely by mules. Fajardo[3] found that the chemical analysis of *Indigofera endecaphylla* closely approximated that of peanut hay which probably was responsible for his later experiments with horses in which he compared the feeding of hay from this plant with peanut hay. The consumption of *I. endecaphylla* was less than that of three varieties of peanut hay; no mention was made of any evidences of toxicity. Davis and Villalobos[4] made observations on *I. endecaphylla* at the Soil Conservation Research Station at Mayaguez, Porto Rico. They reported that the species compared favorably with *Melinis minutiflora* in forage production and that the chemical analysis showed that it should have a high value as a stock feed.

Following the policy of the authors of testing the toxicity of newly introduced plants, two white New Zealand rabbits were grazed on a plot of *Indigofera endecaphylla* at Gainesville, Fla., during the season of 1933. One animal died on the sixth day; the other rabbit was removed from the plot after the development of the first symptoms of illness. It recovered when fed a normal diet.

In the fall of 1934, six white New Zealand rabbits were grazed on a plot of *Indigofera endecaphylla* F.P.I. No. 67844 (introduced from Buitenzorg, Java). Five rabbits died in from 6 to 15 days, while the sixth refused to eat the plant.

From two to four rabbits were grazed on plots of *Indigofera endecaphylla* F.P.I. 77296 (introduced from Peradenlya, Ceylon) during 1935 and 1936; all of these rabbits died showing similar symptoms.

Most of the rabbits ate the plant ravenously when first placed upon the plots. After the second day, however, the plant was consumed less rapidly and in some instances scarcely at all. In addition to being allowed to graze this plant, a small amount of commercial feed was supplied daily. As a general rule, the rabbits consumed less commercial feed after the third day and continued to eat less until all feed was refused. The mucous membranes of the eyes, mouth, and the ears became pale. The animals showed some emaciation even though the period of illness was comparatively short. General weakness was apparent in the terminal stages of illness. In 5 of 12 rabbits the rear quarters apparently were paralyzed. Respirations became feeble. A slight mucous discharge from the nose and a watery discharge from the eyes occurred. Death occurred in from 6 to 17 days in all cases in which the animals were allowed to graze the plant. In instances in which animals were not given commercial feed, death was hastened.

Three of the 12 rabbits showed a marked reduction in total erythrocytes when blood counts were made on the day of death, the lowest count being 2,650,000 per cmm. The erythrocyte count in the remain-

[2] MUNDY, H. G. Twenty-one years of plant introductions and trial in Southern Rhodesia. Rhod. Agr. Jour., 19:512. 1932.

[3] FAJARDO, ALBELARDO J. A study of peanut and Endecaphylla, Jacq. as forage crops. Philippine Agr., 23:140–155. 1934.

[4] DAVIS, R. L., and VILLALOBOS, B. F. Trailing indigo, a promising leguminous forage plant. Soil Conservation, 29–30. July, 1940. (S. C. S. Puerto Rico Div.)

ing animals did not vary greatly from normal. The hemoglobin reading (Sahli) was reduced in all cases from 10 to 32 points, the lowest reading being 58. Leukopenia occurred in six animals, the lowest leucocyte count being 2,200 per cmm. There was no material change in the differential count, neither was there any correlation between the development of leukopenia and anemia.

The principal macroscopic lesions were observed in the liver and kidneys. In the less acute cases, the liver was lighter in color than normal and irregularly congested. Foci of necrosis were common but usually confined to limited areas. In the more acute cases the liver was golden brown in color and showed considerable bile pigmentation. The kidneys often were pale and irregularly congested; the medulla usually showed more marked congestion than the cortex.

Histological examination showed the hepatic cells to be in a state of cloudy swelling, irregular foci of necrosis surrounding the central veins and congested areas. General congestion and slight edema prevailed in the kidneys; the tubular epithelium showed marked cloudy swelling. Congestion also occurred in the lungs, spleen, and myocardium. Cloudy swelling was evident in the cells of the adrenal glands, the surface and glandular epithelium of the intestines, the myocardium, and the smooth muscle of the capsule and tracheculae of the spleen. The lymph nodes and lungs showed considerable edema.—M. W. Emmel, *Veterinarian, Florida Agricultural Experiment Station, Gainesville, Fla.*, and G. E. Ritchey, *Associate Agronomist, Florida Agricultural Experiment Station and the U. S. Dept. of Agriculture, cooperating.*

AGRONOMIC AFFAIRS

THE LICENSING OF AGRONOMISTS

An Act of the Legislature of Porto Rico approved by the Governor on April 9, 1941, establishes a Board of Examiners of Agronomists to issue licenses for the practice of the profession of agronomy in Porto Rico to persons possessing certain qualifications set forth in the Act. These qualifications include the holding of a degree of bachelor of science in agriculture from an accredited university or college in the United States or in Porto Rico or the holding of a bachelor of science degree in forestry, horticulture, zootechny, soils, agricultural economics, or crops, with basic training in botany, zoology, horticulture, entomology, soils, general chemistry, bacteriology, pathology of plants, or plant physiology.

Licenses to practice the profession of agronomy will be granted for life upon recommendation of the Board of Examiners and the payment of a fee of $10. The Act does not apply to persons holding public office the duties of which must be discharged by an agronomist at the time that the Act took effect. Professor Rafael A. Toro of the College of Agriculture of the University of Porto Rico has been named chairman of the Board.

The Act also provides for an Agronomist Association of Porto Rico to be composed of those persons licensed to practice the profession of

agronomy in the Island, providing a majority of them agree to the formation of such an Association in a referendum.

AN ACCOMMODATIONS COMMITTEE

A COMMITTEE composed of Dr. A. G. McCall, Chairman, and including A. M. O'Neal, J. W. McKericher, O. A. Aamodt, and H. R. Smalley has been named to aid members of the American Society of Agronomy and the Soil Science Society of America in finding rooms for the meetings of these organizations in Washington in November. The membership of the two societies is to be canvassed with regard to individual needs for accommodations and efforts made to secure suitable rooms for everyone attending the meetings.

BIBLIOGRAPHY ON THE MINOR ELEMENTS

A SECOND supplement to the third edition of the Bibliography of References to the Literature on the Minor Elements and Their Relation to Plant and Animal Nutrition, as originally compiled by Dr. L. G. Willis of the North Carolina Agricultural Experiment Station, has just been released by the Chilean Nitrate Educational Bureau, Inc., 120 Broadway, New York City.

As in the first supplement to the third edition, the second supplement also includes element, botanical, and author indices.

NEWS ITEMS

ON MAY 1, L. S. Mayer was transferred from Knoxville, Tenn., to the Washington office of the Division of Cereal Crops and Diseases where he will assist Dr. M. T. Jenkins in corn breeding. Mr. Mayer has been engaged in cooperative corn breeding work in Tennessee for the past 19 years where he produced several outstanding white hybrids that have proved especially productive over a wide section of the South.

—A—

DOCTOR FRANK A. HAYES, Senior Soil Scientist, in charge of soil surveys in the Central and Northern Great Plains, Division of Soil Survey, U. S. Dept. of Agriculture, and Professor of Soil Science at the University of Nebraska, Lincoln, Nebr., died suddenly on May 13.

—A—

ON APRIL 18, A. M. Baisden, Superintendent of the Virginia Agricultural Experiment Station at Orange, Virginia, was called to active duty as a 1st Lt. at Fort Bragg, North Carolina. His place was filled by A. B. Johnson, an agronomy graduate at V. P. I. in 1940.

—A—

ON FEBRUARY 26, Ashton Sinclair, Assistant Agronomist assigned to soil survey, was inducted into the Army as a draftee and was assigned to the 1st Armored Division at Fort Knox, Kentucky. T. R. Watkins, a general agricultural graduate at V. P. I. in 1940, was employed on April 6 to fill the vacancy.

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THE INFLUENCE OF ANY INTERNAL GENETIC CHANGE IN A STANDARD VARIETY OF COTTON UPON FIBER LENGTH[1]

JERRY H. MOORE[2]

COTTON growers sometimes complain about their varieties "running out" after the varieties are planted for several seasons. Observation of seed stocks from "run down" or "run out" varieties has shown that the seed appeared to be mixed with those of other varieties. "Black" or "naked" (fuzzless) seed are usually conspicuous in "run out" varieties, and growers soon notice such seed, since the naked condition, besides being easily seen, is apparently linked with a low lint percentage. Moore and Shanklin[3] found that growers who started with seed of an improved or standard variety could keep it pure for four seasons or longer if proper precautions were taken to prevent cross-pollination by foreign seed stocks in the field or mechanical mixing of planting seed at the gin. They also noted that the fiber length of cotton produced from mixed or "run down" varieties was usually very irregular. Moore and Stutts[4] reported relatively pure seed and favorable spinning results from seed stocks originally derived from a registered variety and grown by careful farmers for three to four years. They noted the poor spinning quality of cotton produced from mixed seed stocks originally derived from a registered variety and grown by careless farmers for three to four years.

The main purpose of the work reported here was to measure the influence of any internal genetic change within a standard variety of cotton upon fiber length where cross-pollination with other varieties was avoided.

MATERIALS AND METHODS

A strain of the Mexican variety of cotton bred at the North Carolina Station

[1]Contribution from the Department of Agronomy, North Carolina Agricultural Experiment Station, Raleigh, N. C. Published with the approval of the Director as Paper No. 120 of the Journal Series. Received for publication January 20, 1941.

[2]Cotton Technologist.

[3]MOORE, J. H., and SHANKLIN, J. A. Source and care of cotton planting seed in relation to the length of staple. N. C. Agr. Exp. Sta. Tech. Bul. 42. 1931.

[4]MOORE, J. H., and STUTTS, R. T. Spinning quality of cotton in relation to seed purity and care of seed-stocks. N. C. Agr. Exp. Sta. Tech. Bul. 45. 1934.

for several years and eligible for registration was selected as the standard. This strain originated from a single open-pollinated plant of the Mexican variety. The strain had been selected and rogued for seven years and crossing with other varieties had been prevented. The plant type, seed characters, and fiber length appeared to be relatively uniform and stable. The large, very uniform seed bore a heavy covering of white fuzz.

Seed of the 1930 crop of the standard variety were saved for planting of future crops. Cotton from each crop was grown near Raleigh on a field at the Central Farm where only strains of the Mexican variety were grown.

In 1931 some seed of the 1930 crop from the standard variety were planted in two rows each 190 feet long, and during the summer two blooms on each plant were self-pollinated. At picking time 100 self-pollinated bolls were picked from as many plants and placed in a labeled bag, and 100 open-pollinated bolls were also picked from these plants and put into a labeled bag. The seed cotton in each bag was ginned and the seed saved for planting. One-half of the self-pollinated seed was planted in two rows and one-half of the open-pollinated seed was planted to two other rows in 1932. The seed remnants were saved for planting in 1934. During the blooming period in 1932, two blooms were self-pollinated on each plant grown from self-pollinated seed, and at harvest time, 100 self-pollinated bolls were picked from as many plants and placed in a labeled bag. One hundred open-pollinated bolls were also picked from as many plants grown from open-pollinated seed and put into a labeled bag. The bags of cotton were ginned, and one-half of the seed from each bag was saved for planting in 1934. In 1933 one-half of the self-pollinated seed from the 1932 crop was planted in two rows and one-half of the open-pollinated seed planted in two other rows. The same procedure as was used for the 1932 crop gave 100 self-pollinated bolls and 100 open-pollinated bolls as samples from the 1933 crop. The samples were ginned and stored for planting.

In 1934 self-pollinated and open-pollinated seed from the 1931, 1932, and 1933 crops were planted in rows according to the plan shown in Table 1. Registered seed of the 1930 crop were planted and used as a check.

During the blooming period in 1934 one white bloom on each plant of each row was marked with a dated tag in an attempt to obtain bolls developing under similar environmental conditions. Because of very heavy weevil damage many of the tagged bolls were ruined and samples of sufficient size could not be obtained from them; therefore, it was necessary to use bolls developing from undated flowers as material for the samples. One hundred locks (a lock is the seed cotton in one locule) were picked from undated bolls (all of which opened on approximately the same date) of 100 plants on each row and put into a labeled bag.

In the laboratory one seed from the middle of each of the 100 locks in the sample was removed and the fibers on each seed were combed out at right angles to the longitudinal axis of the seed. Combed staple on seeds has been illustrated by the author.[5] The combed staple length of each seed was measured to the nearest 32nd of an inch; and the mean fiber length, standard deviation, standard error, and coefficient of variability were calculated for each sample. These values are presented in Table 1.

One seed from near the middle of each of 100 locks was taken from each sample coming from rows 1, 8 (check, 1930 registered seed), 6 (open-pollinated seed from the 1933 crop), and 7 (self-pollinated seed from the 1933 crop). Each 100-seed sample was ginned by hand, and after thorough mixing of the lint the distribution

[5]Moore, J. H. The value of single lock samples as a measure of seed purity in cotton. Jour. Amer. Soc. Agron., 26:781–785. 1934.

of fiber length was determined on a Baer sorter. Four 100-milligram lots of lint were sorted in each sample. The data are shown in Table 2 and Fig. 1.

All the fiber measurements were made in a laboratory where a temperature of 70° F and a relative humidity of 65% were maintained.

RESULTS AND DISCUSSION

The combed fiber length on seeds grown in 1934 from seed stocks having a common origin is contained in Table 1 in which the history of each lot of seed is also described. A comparison of the coefficients of variability in the table indicates no real variation difference among lots. The largest difference shown by any comparison is between lots 4 and 5 and amounts to 1.8% (7.9 to 6.1%). The statistical analysis of the mean combed fiber length indicates that differences within certain pairs of lots are significant; but since there is a significant difference between the two check rows, no satisfactory interpretation can be made relative to differences between means. The data do indicate, however, that the mean combed staple length has been

TABLE 1.—*The combed fiber length on seeds from 100 random plants of each lot of cotton grown from the Mexican 58 variety in 1934.*

Lot or row No.	History of seed planted in 1934	Av. length and standard error, inches	Standard deviation, inches	Coefficient of variability, %
1	Check, registered seed of the 1930 crop	0.928±0.0069	0.069	6.4
2	Open-pollinated seed of the 1931 crop (progeny of registered seed of the 1930 crop)	0.977±0.0068	0.068	6.9
3	Self-pollinated seed of the 1931 crop (progeny of registered seed of the 1930 crop)	0.956±0.0061*	0.060	6.3
4	Open-pollinated seed from the 1932 crop derived from open-pollinated seed of the 1931 crop	0.980±0.0061	0.060	6.1
5	Self-pollinated seed from the 1932 crop derived from self-pollinated seed of the 1931 crop	0.949±0.0075	0.075	7.9
6	Open-pollinated seed from the 1933 crop derived from open-pollinated seed of the 1932 crop	0.963±0.0067*	0.065	6.8
7	Self-pollinated seed from the 1933 crop derived from self-pollinated seed of the 1932 crop	0.953±0.0073	0.073	7.7
8	Check, registered seed of the 1930 crop	0.963±0.0060	0.060	6.2

*95 plants.

TABLE 2.—*The distribution of fiber length in hand-ginned samples of cotton grown from the Mexican 58 variety in 1934.*

Lot or row No.	History of seed planted in 1934	Class lengths in 32nds of an inch and percentage of each class by weight							
		39	35	31	27	23	19	15	11, 7, and 3 combined
1	Check, registered seed of the 1930 crop	4.25	15.26	31.21	24.63	10.45	7.11	2.81	4.28
6	Open-pollinated seed from the 1933 crop derived from open-pollinated seed of the 1932 crop	5.85	25.84	33.27	16.31	8.23	3.58	1.58	5.34
7	Self-pollinated seed from the 1933 crop derived from self-pollinated seed of the 1932 crop	5.46	16.62	33.27	19.01	10.40	5.24	2.01	7.99
8	Check, registered seed of the 1930 crop	4.86	20.34	31.61	22.61	11.17	3.56	1.62	4.23

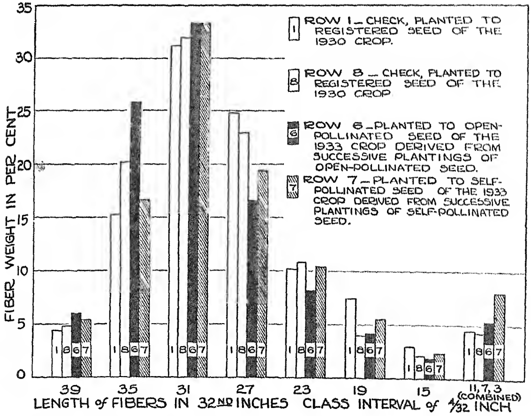

FIG. 1.—The distribution of fiber length by weight in hand-ginned samples of lint produced from the original standard seed and from standard seed mass-selfed and open-pollinated, respectively, for three successive seasons.

maintained in the successive progenies grown, respectively, from self-pollinated and open-pollinated seed.

The distribution of fiber length as determined on the Baer sorter is shown in Table 2 and Fig. 1 for lots 1, 8, 6, and 7. Observation of this figure and of the table does not seem to reveal any real differences between the lots. There is no reason to believe that successive planting of the standard seed for four years was correlated with a decrease of either fiber length or uniformity of length.

While no special studies were made of any changes in plant type and seed, close observation did not show any change in these factors.

SUMMARY

In order to measure the influence of any internal genetic change in a standard variety of cotton upon fiber length, mass-selfed and open-pollinated progenies of a Mexican strain of American upland cotton (*Gossypium hirsutum* L.) were planted for three successive years on a field at the Central Farm, where only Mexican strains were grown.

No change was noted in the combed fiber length or in its variability after one, two or three years of either mass-selfing or open-pollinating.

Arrays made on the Baer sorter indicate no real differences in the fiber length distribution of the ginned staple in a comparison of mass-selfed and open-pollinated seed stocks with the original seed at the end of four seasons.

Observations were made of plant type and seed and apparently there was no noticeable change in either of these factors.

The results given herein and observations made of "run out" varieties indicate that registered varieties or varieties eligible for registration do not "run out" as measured by length of fiber where contamination of seed is avoided.

THE DETERMINATION OF SMALL AMOUNTS OF EXCHANGEABLE POTASSIUM IN SOILS, EMPLOYING THE SODIUM COBALTINITRITE PROCEDURE[1]

N. J. VOLK[2]

DURING a previous investigation (6)[3] of the cobaltinitrite method of precipitating potassium, an attempt was made to control conditions so that the composition of the precipitate would be $K_2NaCo(NO_2)_6.H_2O$. This involved a very careful manipulation at several points during the procedure to avoid the formation of $KNa_2Co(NO_2)_6.H_2O$ and $K_3Co(NO_2)_6.H_2O$. A precipitate having a composition of $K_2NaCo(NO_2)_6.H_2O$ is formed in a water solution when the concentration of sodium is below 0.4%, the concentration of the $Na_3Co(NO_2)_6.H_2O$ is 3.5%, and the temperature is kept between 0° and 4° C. Any appreciable deviation from these conditions will result in an alteration of the composition of the precipitate.

Lohse (2) has shown, likewise, that when precipitation takes place in an alcohol-water medium, the composition of the precipitate can be represented by the formula $(K/Na)_3Co(NO_2)_6$. In this case, the ratio of K to Na depends on the conditions existing during precipitation. Several modifications of the cobaltinitrite method have been proposed by various workers (1, 3, 4, 5, 7).

Results at this laboratory indicate that the precipitation of potassium as $K_2NaCo(NO_2)_6.H_2O$ is not sufficiently sensitive and accurate for soils containing small amounts of replaceable potassium. About 15% of all Alabama soils contain less than 40 pounds of replaceable potassium per acre and 30% contain less than 60 pounds.

It is the purpose of this paper to present results obtained from a study of the factors affecting the precipitation of potassium as potassium sodium cobaltinitrite and to give the details of the method finally adopted for the determination of the replaceable potassium of soils.

PRECIPITATION FACTORS

When potassium was precipitated by adding various quantities of $Na_3Co(NO_2)_6.H_2O$ to solutions of constant volume containing different amounts of sodium (added as sodium acetate), the data represented by the curves in Fig. 1 were obtained. It will be noted that as the concentration of the precipitating reagent was increased, the percentage of potassium in the precipitate decreased. For concentrations of the precipitating reagent between 10% and 20%, the change in the potassium content of the potassium sodium cobaltinitrite precipitate is very small as compared with the change occurring at concentrations in the region of 3.5%. Thus, the higher the concentration of the precipitating reagent within certain limits, the more accurate

[1]Contribution from the Department of Agronomy and Soils, Alabama Agricultural Experiment Station, Auburn, Ala. Published with the approval of the Director. Received for publication February 12, 1941.

[2]Soil Chemist.

[3]Figures in parenthesis refer to "Literature Cited", p. 688.

should be the results. For this reason it is recommended that, instead of using a concentration of 3.5% $Na_3Co(NO_2)_6.H_2O$ in order to produce the theoretical composition of $K_2NaCo(NO_2)_6.H_2O$, a concentration of 10% be used which, although giving a precipitate containing a lower percentage content of potassium, is a precipitate less subject to change in composition, since it will not be formed at a critical point.

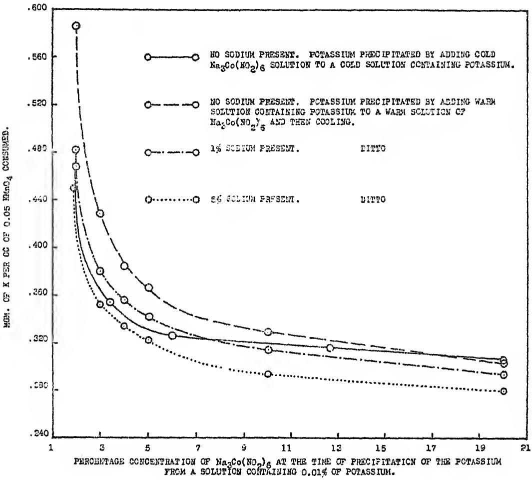

FIG. 1.—Variations in the amount of potassium contained in precipitated potassium sodium cobaltinitrite (expressed as mgm of K per cc of 0.05 N $KMnO_4$ consumed) when potassium is precipitated in the presence of different amounts of sodium (present as sodium acetate) and sodium cobaltinitrite at room temperature and at 3° C.

It is a known fact that the presence of increasing amounts of sodium causes the precipitate formed to be relatively lower in potassium. In Fig. 1 results are shown which reveal the degree to which various concentrations of sodium affect the composition of the precipitate.

Sodium not only reduces the content of potassium in the precipitate, but it also increases the sensitivity of the method, i.e., decreasingly smaller quantities of potassium can be precipitated in aqueous solutions as the concentration of sodium is increased. Results in Table 1 indicate that potassium, when present in concentrations of

less than 0.0015%, will not be completely precipitated by $Na_3Co(NO_2)_6.H_2O$ at a concentration of 3.5%. However, in the presence of 2% sodium (added as the acetate) and 10% $Na_3Co(NO_2)_6.H_2O$, potassium will be completely precipitated from aqueous solutions containing as low a concentration as 0.0005% of potassium.

TABLE 1.—*The effect of sodium on the sensitivity of the sodium cobaltinitrite method of precipitating potassium from dilute solutions.*

Potassium present, mgm K	Percentage concentration of K in the solution	Potassium recovered in the presence of 2% Na (as sodium acetate), mgm K	Potassium recovered in the absence of Na, mgm K
16.00	0.0800	15.99	15.76
8.00	0.0400	8.07	7.91
4.00	0.0200	4.09	4.05
2.00	0.0100	2.00	2.06
1.00	0.0050	1.01	1.01
0.50	0.0025	0.50	0.52
0.40	0.0020	0.41	0.39
0.30	0.0015	0.30	0.18
0.20	0.0010	0.19	0
0.10	0.0005	0.11	0

Some analysts add the precipitating reagent very slowly to the cooled solution containing potassium and others add it rapidly. Indications are that when a precipitate forms during the process of adding the precipitating reagent, the results are low, but when no precipitate forms during the addition, the results will be satisfactory (Table 2). The best results were obtained at this laboratory by rapidly adding the solution containing the potassium to the solution of sodium cobaltinitrite (both solutions being maintained at room temperature during the mixing process and then cooled to and maintained at 3° C for at least 5 hours).

TABLE 2.—*The recovery of potassium as affected by the method of mixing the precipitating reagent with the solution containing the potassium.*

Potassium present, mgm*	Potassium recovered on slowly adding the cooled precipitating reagent to the cooled solution containing the potassium, mgm	Potassium recovered on rapidly adding the cooled precipitating reagent to the cooled solution containing the potassium, mgm	Potassium recovered on rapidly adding the potassium solution to the precipitating reagent both at room temperature and then cooled to 3 C after mixing, mgm
10.00	9.27	9.49	10.02
5.00	4.93	4.98	5.09
1.00	1.00	1.00	1.01
0.50	0.52	0.51	0.50

*Only solutions containing more than 5 mgm of potassium gave rise to precipitation during the addition of $Na_3Co(NO_2)_6.H_2O$.

In order to lower the conversion factor (mgm of K per cc of 0.05 N potassium permanganate consumed) to a minimum, to reduce precipitation errors to a minimum, and to increase the sensitivity of the method to a maximum, precipitation exactly as $K_2NaCo(NO_2)_6.H_2O$ was discarded at this laboratory. Fig. 1 shows that precipitation in the presence of 1% to 5% sodium and 10% sodium cobaltinitrite takes place at a much more stable place on the curve. The conversion factor drops from 0.355 mgm of K to 0.329, 0.315, 0.303, and 0.294 for concentrations of Na of 0%, 1%, 2%, and 5%, respectively.

PROCEDURE FOR REPLACEABLE POTASSIUM IN SOILS

The analytical procedure finally adopted as a result of this study of the factors affecting the precipitation of potassium is given below:

Thirty grams of 30-mesh air-dry soil are placed in 150 cc of normal ammonium acetate solution (pH 6.8) and the mixture is agitated for 15 minutes by means of a dispersing machine. The suspension is filtered on a Buchner funnel, and the soil leached 10 times with 25 cc portions of normal ammonium acetate solution. The combined extract and leachate are then evaporated to dryness at 60° C, the organic matter destroyed with 10% H_2O_2, and the ammonia expelled by evaporating to dryness after washing down the sides of the beaker with about 50 cc of water containing 3 drops of 10% NaOH. The beaker is then removed from the hot plate, allowed to cool, the residue treated with 15 cc of approximately 0.16 N acetic acid and filtered into a dry beaker.

A 10-cc portion of the filtrate (representing 20 grams of soil) is added rapidly at room temperature to 10 cc of 20% sodium cobaltinitrite solution containing an additional 4% of sodium as the acetate. The mixture is placed in a refrigerator at 3° C for at least 5 hours, filtered on an asbestos pad, washed with cold water, and titrated according to the procedure of Volk and Truog (6) with standard permanganate and oxalate.

By this modified method, 1 cc of 0.05 N $KmnO_4$ equals 0.303 mgm of K.

RESULTS OBTAINED

Employing the procedure just described, each of two analysts working independently of each other analyzed the same lot of 782 soils. The replaceable potassium content of these soils varied between 14 and 540 pounds per acre. To avoid compensation errors in determining the average error that would be expected between duplicate analyses, the 782 low results were compared with the 782 high results irrespective of the analyst. The average difference was 4.4 pounds of potassium per acre. For soils containing small amounts of potassium (100 pounds or less), the difference between the two analysts' results was usually less than 4 pounds, and for high amounts (300 pounds or higher) of potassium the difference often reached a magnitude of 15 pounds per acre. A lot of 23 samples of soil selected at random were all analyzed by the writer and also by each of two other analysts. The results thus obtained are given in Table 3.

TABLE 3.—*The amounts of replaceable potash found in 23 soils by three analysts working independently of each other and using the modified cobaltinitrite method described herein.*

Soil No.	Pounds of replaceable potassium per acre		
	John Davis	John Rice	N. J. Volk
117 b	14	14	15
116 b	22	23	22
111 b	32	31	33
109 b	37	39	37
118 c	46	45	48
5 b	53	51	50
1 c	64	64	64
18 c	67	71	71
12 c	75	75	78
13 a	89	92	85
11 c	103	100	103
31 b	117	117	117
96 a	142	152	146
256 a	149	149	151
6 b	164	167	164
273 a	184	178	183
294 a	191	194	195
169 a	203	199	200
332 a	217	209	213
266 a	254	259	257
278 a	312	309	318
276 a	355	366	359
270 a	476	465	476
Average	146.3	146.5	147.2

SUMMARY

This investigation was undertaken for the purpose of developing, if possible, a procedure for measuring the small amounts of replaceable potassium found in many soils, e.g., in Alabama about 15% of the soils contain less than 40 pounds per acre of replaceable potassium.

Displacement of the potassium is achieved by leaching the soil with ammonium acetate. The displaced potassium, after being freed of ammonia and organic matter, is taken up in 0.16 normal acetic acid and precipitated as potassium sodium cobaltinitrite. Complete precipitation is obtained by rapidly adding the solution containing the potassium to an equal volume of 20% sodium cobaltinitrite containing an additional 4% of sodium as the acetate. Mixing of the solutions is done at room temperature and precipitation is allowed to go to completion at about 3° C. The amount of potassium present is finally determined by dissolving the washed precipitate in water and titrating with permanganate.

The method is sensitive to a concentration of potassium as low as 0.0005% (0.1 mgm per 20 cc).

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PRELIMINARY RESULTS WITH MULCHES APPLIED TO ERODED WASTELAND SOWN TO LESPEDEZA[1]

B. H. Hendrickson and Roy B. Crowley[2]

The utilization of steeply sloping, severely eroded, and gullied "clay-gall" land, abandoned for crop land purposes and regarded as practically worthless for agriculture, is a problem of importance in the hilly sections of the Southeast. This paper reports the results of mulching tests on land of this character.

Organic matter in the form of crop residue material retained on the soil surface for mulching purposes is generally known to be capable of increasing the amount of water entering the soil, as reported by Viemeyer (7).[3] Mulch action is usually credited with interception and dispersal of raindrops and the prevention of pore-clogging and surface compaction or crusting of surface soil.

Bennett (1) reports that surface compaction did not occur under straw mulch. Duley (2) and Duley and Russel (3) have found very markedly increased soil moisture associated with straw mulching, due to increased infiltration and reduced evaporation, and have developed a new duck-foot cultivator for mulch-retaining subsurface tillage for Nebraska conditions.

Peele[4] reports that when green lespedeza hay and green crimson clover hay were applied as a surface mulch to 7% sloping Cecil sandy loam plots at the rate of 4 tons per acre (oven-dry basis), both run-off and erosion were reduced to low values, much lower than when the same hays were incorporated with the soil. Also, crimson clover mulch caused a much larger increase in soil aggregation than when crimson clover hay was incorporated in the soil. In either case, the numbers of fungi and bacteria were increased, and the beneficial effects upon soil aggregation were ascribed to favorable moisture and temperature effects acting as stimuli to microbial activity.

Peele and Moser (5) report lower run-off and erosion losses from Kobe lespedeza plots during late fall and winter months than from cotton plots. The beneficial effects of the lespedeza were attributed largely to the mulch action of the lespedeza residues.

Pieters (6) advises that *Lespedeza sericea* should be mulched after seeding on eroded knolls, gullies, and other places where good seedbed preparation is not possible. Franklin (4) names five benefits of mulching, *viz.*, moisture conservation, seed retention, soil protection, soil improvement, and seedling protection.

Experience at the Southern Piedmont Experiment Station has been that crops generally produce higher yields when mulch is applied or when a mulch is grown in place in good self-mulching or stubble-mulching practices, as in the small grain-lespedeza repeating sequences.

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[1]Contribution from the Southern Piedmont Experiment Station, Watkinsville, Ga. Received for publication February 20, 1941.

[2]Project Supervisor and Senior Foreman-Cooperative Agent, respectively, Southern Piedmont Experiment Station, Watkinsville, Ga.

[3]Figures in parenthesis refer to "Literature Cited", p. 694.

[4]Personal communication.

EXPERIMENTAL

In connection with other field tests devoted to protective land use methods, a few applied mulch tests were begun in the spring of 1939 and continued in 1940 on eroded Cecil clay slopes in the Southern Piedmont of northeast Georgia. Although the plot layouts were not formally planned nor fully replicated, results have been so striking as to warrant their release, provided they are properly interpreted as indicative merely of strong trends.

In the spring of 1939, small plots about 1/8 acre each were selected on 10 to 20% slopes of typically eroded gullied Cecil clay, B horizon, of what was formerly Cecil sandy loam. The plots were disc harrowed, fertilized with 16% superphosphate at the rate of 300 pounds per acre, and sown to Korean or Kobe lespedeza at the rate of 30 pounds per acre. A spike-harrow was used to cover the seed. Individual plots to be mulched were then covered by hand forking with a coating of approximately 3 to 4 tons per acre of waste lespedeza straw, or with mixed grain straw, to depths varying from a trace to 4 inches deep. Check plots were unmulched.

RESULTS

Both varieties of lespedeza responded remarkably well to mulches of 1 to 1¼ inches settled thickness. Yields and measurements of the depth of the mulch were made in the fall of 1939. Stands were very thin or failed where only a trace of mulch had been applied and failed on check plots. Straw over 2 inches deep evidently shaded the seedlings too much, while the thicker layers smothered them out altogether. Hay yields collected by the hoop method in representative areas are shown in Table 1.

TABLE 1.—*First-year lespedeza response to mulching, 1939.*

Variety	Hay yields, tons per acre		Mulch used
	Without mulch	With mulch	
Korean	Failure	1.35	Mixed grain straw
Korean	Failure	1.95	Lespedeza straw
Kobe	Failure	1.67	Mixed grain straw

These small test plots were allowed to mature unharvested seed in 1939. They remained undisturbed through 1940 in order to provide opportunity to measure second year responses of the volunteering crop. In the fall of 1940, when hay yields were again obtained by the hoop method, the straw mulch on the ground was collected and weighed in the air-dry condition and returned to the plot. The results are given in Table 2.

In the spring of 1940, a new set of similar plots was started in a repeated test under like soil and slope conditions, except that 400 pounds per acre of basic slag were applied instead of superphosphate, using two mulched plots for each of the two lespedezas and four alternating unmulched check plots. After disc preparation and sowing, these plots were cultipacked lightly. Lespedeza, rye, and wheat straw were the mulch materials and were applied at rates of 2 to 4

TABLE 2.—*Volunteer lespedeza response to original mulching, second year, 1940.*

Variety	Hay yields, tons per acre		Straw remaining on the land in the fall		
	Without mulch	With mulch	Kind	Amount, tons per acre	Approximate depth, in.
Korean	Failure	1.65	Lespedeza plus lespedeza residues	2.55	3/4
Kobe	Failure	2.20	Mixed grain plus lespedeza residues	2.90	3/4

tons per acre. The results of the previous years were substantially repeated, as shown in Table 3. The 1940 growing season was somewhat more favorable for the growth of lespedezas than was that of 1939.

TABLE 3.—*Lespedeza response to mulching, 1940 tests.*

Variety	Hay yields, tons per acre		Straw remaining on land in the fall		
	Without mulch	With mulch	Kind	Amount, tons per acre	Approximate depth, in.
Korean..	Failure	1.80	Wheat	1.90	1/2
Korean..	No check	2.00	Lespedeza	3.22	1
Kobe....	Failure	0.80	Rye	1.10	1/4
Kobe....	Failure	1.60	Wheat	1.70	1/2
Kobe....	Failure	2.00	Wheat	1.50	1/2

At the Southern Piedmont Experiment Station crop land lespedeza hay yields averaged 1.8 tons per acre of Korean and 2.1 tons per acre of Kobe with comparable fertilization on better land but without applied mulch. Thus it appears that mulched clay-gall areas may be capable of producing lespedeza hay yields approximately equal to those produced on good upland fields when proper amounts of mulch are applied to the clay-gall plantings and when the mulch is spread as evenly as possible at the rate of 3 to 4 tons per acre to produce a settled thickness of about 1 to 1¼ inches.

In order to measure the protective properties of applied mulch, in April 1940 two run-off plots 20.74 feet wide by 70 feet long, located on a 11% slope of Cecil clay loam soil, were disced, fertilized with 600 pounds per acre of basic slag, and planted to Kobe lespedeza, using a 30-pound per acre seeding rate. Approximately 3 tons per acre of wheat straw mulch was applied to one plot, while the other was left unmulched. Table 4 lists the soil and water loss data of record to date for these two plots.

The immediate and almost complete control of both run-off and erosion during the highly erosive season of 1940 and the stimulating effect of mulch upon stand, growth, and yield of Kobe lespedeza

have aroused the interest of all who observed the plots. Seed yields of 129 and 240 pounds per acre from the unmulched and mulched plots, respectively, were combine harvested in the fall of 1940.

TABLE 4.—*Soil and water losses April to September, 1940, from mulched and unmulched Kobe lespedeza plots.*

Treatments	Rainfall, in.	Run-off, %	Erosion, tons per acre
Unmulched check............	25.27	32.75	12.57
Mulched....................	25.27	1.43	0.20

Following seed harvest, the lespedeza residues were left on the land to supplement the approximately ¼-inch layer of wheat straw mulch which still remained on the straw-mulched plot.

DISCUSSION

The application of grain straw and lespedeza straw mulches appeared to be practical as a means of obtaining stands of thick-growing summer annual Korean and Kobe lespedezas on "galled" or "critical" areas in fields where it was necessary also to protect and improve the soil. Good production was obtained from the initial sowing when mulched and fertilized with superphosphate or basic slag. Since the eroded Cecil clay was practically sterile and was known to be moderately acid in reaction and very low in available phosphates, larger per acre applications of lime and phosphate, or the equivalent, than those used in these studies, might well have been made. Low run-off, associated with mulching, increased soil moisture available to the crop on otherwise drouthy land and greatly improved the growing conditions.

No other practice under test, agronomic or otherwise, approached the mulch in effectiveness in reducing soil and water losses. The performance of the mulch was particularly striking because of the extremely erodible conditions of soil and slope on which it was applied.

It was evident also that the mulching created conditions favorable to germination and growth of lespedeza. Similarly fertilized good crop land fields of gentle slope on the Southern Piedmont Experiment Station produced less Kobe lespedeza seed per acre than did the mulched Cecil clay loam run-off plot on the 11% slope.

The mulch "blanket" permitted clear rainwater to filter into the previously tilled, granular clay and clay loam. The seedbed was protected from the full force of the sun, wind, and beating rains, which otherwise induce surface crusting of bare soil. The mulches, anchored to the slopes by the growth of lespedeza, slowed sheet flow, impeded concentrated flow of run-off, and slowed down the entire erosion process to such an extent that erosive volumes and velocities of run-off did not occur.

The run-off data shown in Table 4 indicate that almost 8 inches more of the rainfall remained on the mulched plot than on the unmulched plot. Since steep Cecil clay loam slopes are drouthy, and since the mulch also reduced surface evaporation losses, the indica-

tions were that the improved soil moisture conditions due to mulch had a great deal to do with the good crop of lespedeza produced.

The mulched lespedeza grew rapidly and plants had excellent color. Of the two types of mulches, lespedeza straw proved to be longer lasting and stimulated the larger lespedeza yields.

Mulching of critical areas on farms appears to be well worthwhile and practical, providing low cost mulch materials are available. Very likely *Lespedeza sericea* and Kudzu plantings on steep badly-eroded land will respond to mulching, and there is little doubt that soil, water, and fertilizer losses will be reduced, especially during the first year or two after planting while plant coverage is being developed.

Soil improvement on critical areas associated with mulching and close-growing legume crops should be maintained by using these areas for permanent hay, pasture, or woodland rather than for cultivated row crops.

Since 1 to 1¼ inches of mulch have shown value under critical conditions, smaller amounts of plant residue material, preferably grown in place, may have a relatively similar effect under less erodible soil and slope conditions. This line of thought suggests that more attention to the development of self-mulching cropping methods for the humid Southeast may be well worth investigation.

SUMMARY

A series of preliminary tests dealing with mulching with *grain straw* and with *lespedeza straw* of annual lespedeza seedings on thin, steep, clay-gall lands is reported in connection with which beneficial effects due to mulching have been obtained on stands, growth, yields of the crops, and reduction of soil and water losses.

The plan of growing mulches in place or of self-mulching cropping practices for the better crop lands is suggested by the results obtained in these tests on practically sterile, waste land.

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HOW TO DETERMINE WHICH OF TWO VARIABLES IS BETTER FOR PREDICTING A THIRD VARIABLE[1]

William Dowell Baten[2]

A VERY important problem arising in certain agricultural experiments is the determination of which one of two variables is better for predicting a third variable. For example, measurements are made on the lengths of heads of wheat and counts on the number of spikelets and the number of kernels per head, and it is desired to know whether the number of kernels per head can better be predicted on the average from the length of the heads than from the number of spikelets per head. Can a steer's weight be better predicted on the average from his heart girth than from some other body measure? Can the area of a bean leaflet be better predicted from its length than from its width?

The natural way to go at solving this problem is to test for significance between the standard errors of estimate arising from the errors from the two predicting values. Assume that predicting linear equations have been found for predicting the number of kernels per head of wheat from the length of the head and from the number of spikelets per head and that these equations together with the standard errors of estimate are

$$\tilde{y}=\bar{y}+b(x-\bar{x}) \quad ; \quad \sigma_e=\sigma_y\sqrt{1-r^2_{yx}}$$

and

$$\tilde{y}=\bar{y}+d(z-\bar{z}) \quad ; \quad \sigma_e=\sigma_y\sqrt{1-r^2_{yz}}$$

where $\tilde{y}$, $\bar{y}$, x, and z represent, respectively, the predicted number of kernels per head, mean number of kernels, length of the head, and the number of spikelets per head, and r_{yx} and r_{yz} the respective correlation coefficients. The difficulty in testing the two standard errors of estimate arose from the fact that they were correlated in a peculiar manner. Hotelling[3] solved the problem for the first time and gave a test for testing significance. Since this test is so recent (November 1940) and might be overlooked for several years by agriculturists not interested in derivations of formulas, and since it has been desired by many research workers, it seems fitting to present several applications of this helpful test and bring it to the attention of those interested.

APPLICATIONS

The first application pertains to determining whether or not the length of a head of wheat is better for predicting on the average the number of kernels per head than the number of spikelets with grain

[1]Contribution from the Department of Mathematics, Michigan State College, East Lansing, Mich. Journal Article No. 512 (n.s.), Michigan Agricultural Experiment Station. Received for publication March 8, 1941.

[2]Research Associate in Statistics.

[3]Hotelling, Harold. The selection of variates for use in prediction with some comments on the general problem of nuisance parameters. Ann. Math., Statistics Vol. XI:271–283. 1940.

per head. It is assumed throughout this paper that there are linear relations between the variables. One hundred heads of American Banner wheat were taken at random from the wheat crop at the

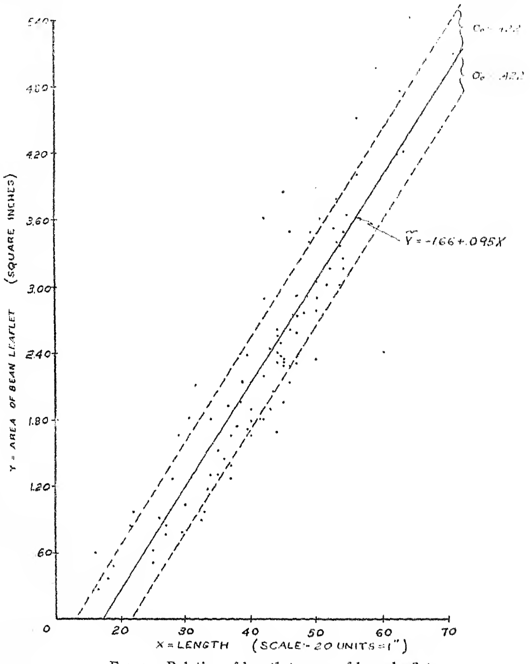

FIG. 1.—Relation of length to area of bean leaflet.

Michigan Experiment Station.[4] Scatter diagrams were made of the data and revealed linearity. The predicting equations, together with the standard errors of estimate and correlation coefficients found by the method of least squares, are as follows:

$$\tilde{y}=28.86+5.27(x-8.92);\quad \sigma_e=5.04;\quad r_{yx}=0.795$$
$$\tilde{y}=28.86+2.96(z-15.93);\quad \sigma_e=3.87;\quad r_{yz}=0.885$$
$$r_{xz}=0.914$$

[4]H. M. Brown of the Farm Crops Department supplied the wheat data.

where x = length in cm, $\bar{y}$ = predicted number of kernels per head, z = number of spikelets with grain, and σ_e = standard error of estimate.

The standard error of estimate arising from predicting the number of kernels per head from the number of spikelets with grain per head is 3.87 kernels and is smaller than that of 5.04 kernels arising from predicting the number of kernels per head from the length per head. But is 3.87 significantly smaller than 5.04? If it is not significantly smaller, the length measurement might be used for it is much easier to measure the length of the heads than to count the spikelets with grain. Hotelling's test is as follows:

$$t = (r_{yz} - r_{yx}) \sqrt{\frac{(n-3)(1+r_{xz})}{2D}},$$

where n is the number of heads and D is a third order determinant made up of the linear correlation coefficients and is

$$D = \begin{vmatrix} 1 & r_{yz} & r_{yx} \\ r_{yz} & 1 & r_{xz} \\ r_{yx} & r_{xz} & 1 \end{vmatrix}$$

where r_{yz} is larger than r_{yx}.

In the case under consideration,

$$t = (0.885 - 0.795)\sqrt{\frac{97(1+0.914)}{2(0.0355)}} = 0.090(51.14) = 4.60,$$

and

$$D = \begin{vmatrix} 1.000 & 0.885 & 0.795 \\ 0.885 & 1.000 & 0.914 \\ 0.795 & 0.914 & 1.000 \end{vmatrix} = 0.0355.[5]$$

By examining "Students" t table at $n-3 = 97$ degrees of freedom, it is seen that there is a highly significant difference between the two standard errors of estimate which means that on the average the number of kernels per head can be predicted better from the number of spikelets per head with grain than from the length per head.

The next example is to determine whether or not areas of bean leaflets can be better predicted from lengths than from widths. Measurements were made on 220 center leaflets of navy beans.[6] Areas were obtained from blue prints by a planimeter. From these areas, 100 were taken at random and the following predicting equations, together with standard errors of estimate and correlation coefficients, were obtained:

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[5]The value of the third order determinant is

$$\begin{vmatrix} a & b & c \\ d & f & g \\ h & j & k \end{vmatrix} = a.f.k + d.j.c. + h.b.g - c.f.h - g.j.a - b.d.k$$

[6]The data on navy beans were supplied by J. F. Davis, Research Assistant in Soils, Michigan Experiment Station.

$$\tilde{y}=23.50+0.095(x-42.31);\ \sigma_e=0.422;\ r_{yx}=0.927$$
$$\tilde{y}=23.50+0.119(z-34.09);\ \sigma_e=0.290;\ r_{yz}=0.966$$
$$r_{xz}=0.891,$$

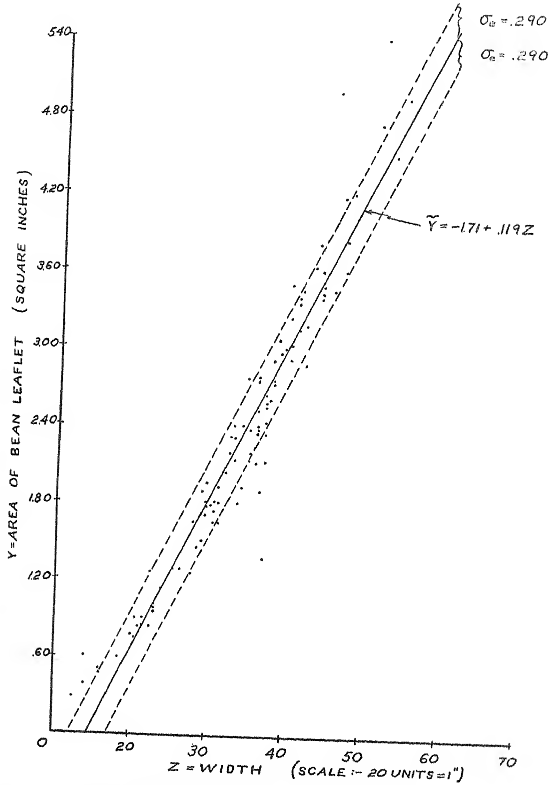

FIG. 2.—Relation of width to area of bean leaflet.

The value of t is

$$t=(0.966-0.927)\sqrt{\frac{97(1+0.891)}{2(0.00938)}}=0.039(98.882)=3.86$$

where

$$D=\begin{vmatrix} 1.000 & 0.966 & 0.927 \\ 0.966 & 1.000 & 0.891 \\ 0.927 & 0.891 & 1.000 \end{vmatrix}=0.00938.$$

The value of t for 97 degrees of freedom indicates that there is a significance between the standard errors of estimate and that the area of the center leaflet of these beans can be predicted better from width measurements than from length measurements.

Scatter diagrams of these data are shown in Figs. 1 and 2, together with the predicting straight lines and standard errors of estimate. This t test determines whether or not the widths of the bands on each side of the predicting straight lines are significantly different. It is not necessary to find the predicting equations or the standard error of estimates to apply Hotelling's test, for it can be applied to the correlation coefficients; neither do charts have to be made to apply the test. Finding the predicting equations, computing the standard errors of estimate, and drawing the straight lines and bands of "normality" through the scatter diagrams do help one to understand a little better what is accomplished by the test.

SUMMARY

Two examples from agriculture have been presented to show how to determine which of two variables is better for predicting a third. It is hoped that this brief paper will call this important matter to the attention of others who are interested in this test.

A BOTANICAL AND YIELD STUDY OF PASTURE MIXTURES AT BELTSVILLE, MARYLAND[1]

Paul R. Henson and Mason A. Hein[2]

FUNDAMENTALLY, the purpose of sowing a complex mixture for permanent pasture is to increase the total production of the pasture, improve the quality, and at the same time provide more uniform production during the grazing season. Since each grass has its peak period or periods of production, the end to be attained is to so blend the seed mixture that the periods of maximum production of the individual species do not occur simultaneously. Mixtures of different grass species also may insure a more uniform cover because of their adaptation to varying environmental conditions. Old permanent pastures in the Middle Atlantic States on soils of medium to high fertility are composed largely of Kentucky bluegrass and white clover. The objection to this mixture is that it usually provides little grazing during the seasons of dry warm weather from June 15 to August 15. Although Kentucky bluegrass is one of the most important pasture grasses in this region, it is obvious that if another grass could be found which would thrive in association with it and increase the carrying capacity during this period the value of pastures in this region would be greatly improved.

While the changes in the botanical composition of many complex pasture mixtures have been reported in pasture experiments in this region (4, 5, 7, 11),[3] comparative information on specific mixtures for permanent pastures is meager. Herein are reported the results of 4 years' study of the botanical composition and yields of plots sown on an area of Sassafras silt loam on the Bureau of Dairy Industry farm at Beltsville, Md.

PROCEDURE

The area was plowed in November 1935. Limestone, in accordance with the requirements as determined from acidity tests, was applied at the rate of 2,000 pounds per acre in April 1936, followed by an application of 600 pounds of 16% superphosphate and 200 pounds of muriate of potash per acre. The area was thoroughly disked following the limestone application and again after the fertilizers were applied. During June, well-rotted barnyard manure was applied at the rate of 14 tons per acre and disked thoroughly into the topsoil. The area was fallowed during the summer until the seedbed for the pasture mixtures was prepared in early September.

The eight mixtures tested consisted of Louisiana white clover in combination with one or more grasses adapted to this region. The seed combinations and the rate of seeding are given in Table 1. The seed of the mixtures were carefully

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[1]Contribution from the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. This experiment was conducted at the Beltsville Research Center, Beltsville, Md., on land furnished by the Bureau of Dairy Industry. Received for publication March 15, 1941.

[2]Associate Agronomist and Agronomist, respectively. The experiment was inaugurated by the late H. N. Vinall, Senior Agronomist.

[3]Figures in parenthesis refer to "Literature Cited", p. 708.

weighed by plots and sown September 29, 1936. The test consisted of three replications of systematically arranged plots, each plot measuring 5 by 12 feet. Excellent stands were secured on all plots.

TABLE 1.—*Seed mixtures and rates of seeding of the permanent pasture mixtures.*

Species	Rate of seeding in pounds per acre for mixtures							
	I	II	III	IV	V	VI	VII	VIII
Kentucky bluegrass	20	18	10	8	8	8	—	—
Redtop	—	3	3	3	—	—	—	—
Orchard grass	—	—	8	6	5	5	—	—
Timothy	—	—	—	4	4	4	—	—
Italian ryegrass	—	—	—	—	4	—	—	—
Perennial ryegrass	—	—	—	—	—	4	—	—
Canada bluegrass	—	—	—	—	—	—	20	—
Colonial bent	—	—	—	—	—	—	—	20
Louisiana white clover	4	3	3	3	3	3	4	4
Total	24	24	24	24	24	24	24	24

Plant population counts were not made during 1937, however, the percentage of each species in each clipping was estimated. These estimates were averaged and are given in Table 2 under the column for 1937. On April 13, 1938, the plant population of the plots was determined by estimating the percentage of the area occupied by each species, three 1-foot square areas being used. The later readings were all made with the modified point quadrat as described by Tinney, Aamodt, and Ahlgren (10). The data obtained from the point quadrat readings were analyzed to express the percentage contributed to the pasture cover by each species. The method employed in expressing botanical cover differs from the Levy (6) method in that not only the total "hits" of all vegetation but also of bare space are included in the divisor. The results of the point quadrat readings as expressed by this method were closely comparable to those obtained in the percentage-area method employed in the earlier reading.

The average percentage contributed by each species to the pasture cover as determined by the point quadrat readings on October 31, 1938, June 13 and November 1, 1939, and May 23 and October 14, 1940, is given in Table 2.

Yields from all three replications were obtained in 1937 and 1940 by clipping a strip 27 inches wide through the center of each plot with the lawn mower set to cut to a height of 1¼ inches. The green herbage from the mowed strip was placed in moisture sample bags, weighed immediately, and later dried to a moisture-free condition in a large force-draft oven. Yields are expressed on a moisture-free basis. During 1938 and 1939 only the first replication was clipped, the two other replications being grazed by sheep. Nine clippings were made in 1937, eight in 1938 and 1939, and only four in 1940. The average dry yields in pounds per acre by monthly periods for the 4 years are given in Table 3. The 1937 and 1940 yields were tested for significance by analysis of variance and are shown in Table 4.

RAINFALL 1937–40

The total production and particularly the midsummer production of pasture herbage is dependent very largely on the amount and distribution of rainfall during this period. The monthly rainfall in inches during the grazing seasons for

TABLE 2.—*Average percentage of bare ground and cover supplied by each species of the different pasture mixtures for the 4-year period, 1937–40.*

Species	Pounds of seed sown per acre	Percentage of pasture cover						
		1937*	1938		1939		1940	
			Apr. 13	Oct. 31	June 13	Nov. 1	May 23	Oct. 14
Mixture I								
Bare ground	—	—	1.3	0.6	5.5	1.5	0	0
Sown species, white clover	4	43.7	28.5	6.5	13.8	7.5	18.7	0.7
Sown species, Ky. bluegrass	20	52.3	69.3	83.9	78.9	83.5	77.6	92.7
Volunteer grasses and legumes	—	—	—	—	1.8	1.5	3.2	2.0
Total weeds	—	4.0	0.9	9.0	0	6.0	0.4	4.6
Mixture II								
Bare ground	—	—	1.3	0.7	3.5	2.9	0.4	0
Sown species, white clover	3	36.7	20.4	10.1	10.6	7.2	9.7	1.4
Sown species, Ky. bluegrass	18	54.5	57.4	65.5	64.6	73.9	74.7	82.8
Sown species, redtop	3	7.3	19.6	19.6	18.6	9.4	13.5	6.9
Volunteer grasses and legumes	—	—	—	—	—	—	0.4	0.7
Total weeds	—	1.5	1.3	4.1	2.7	6.5	1.3	8.3
Mixture III								
Bareground	—	—	1.3	0	5.4	1.9	0	0.7
Sown species, white clover	3	29.6	16.5	7.6	10.8	7.1	6.9	4.2
Sown species, Ky. bluegrass	10	55.0	41.1	65.8	64.0	73.5	76.4	66.7
Sown species, redtop	3	6.2	27.1	9.5	10.8	4.5	6.5	2.8
Sown species, orchard grass	8	6.6	12.4	9.5	8.1	7.7	5.1	8.3
Volunteer grasses and legumes	—	—	—	—	—	0.6	2.8	—
Total weeds	—	2.5	1.6	7.6	0.9	4.5	2.3	17.4
Mixture IV								
Bare ground	—	—	1.6	0.7	1.6	1.3	0	0.7
Sown species, white clover	3	28.6	17.5	7.9	13.8	6.5	12.7	2.0
Sown species, Ky. bluegrass	8	43.6	38.0	58.3	59.3	73.4	69.7	80.3
Sown species, redtop	3	5.9	24.2	16.6	14.6	2.6	8.1	5.3
Sown species, orchard grass	6	8.7	13.1	7.3	7.3	5.8	2.7	2.6
Sown species, timothy	4	13.2	4.0	2.0	0.8	0.6	3.6	0.7
Volunteer grasses and legumes	—	—	—	—	—	1.3	2.3	—
Total weeds	—	0	1.6	7.3	2.4	8.4	0.9	8.6

*Average estimate of each species in each clipping.

TABLE 2.—*Concluded.*

Species	Pounds of seed sown per acre	Percentage of pasture cover 1937*	1938 Apr. 13	1938 Oct. 31	1939 June 13	1939 Nov. 1	1940 May 23	1940 Oct. 14
Mixture V								
Bare ground	—	—	3.3	1.4	3.2	1.3	0	0.7
Sown species, white clover	3	45.0	19.6	2.8	12.1	5.4	5.6	2.0
Sown species, Ky. bluegrass	8	30.1	42.6	69.7	71.0	75.8	85.4	83.0
Sown species, orchard grass	5	6.1	20.2	11.0	8.9	11.4	4.7	5.4
Sown species, timothy	4	9.7	10.2	4.1	0.8	1.3	2.3	0.7
Sown species, Italian ryegrass	4	8.7	1.6	2.8	2.4	0	0	0
Volunteer grasses and legumes	—	—	—	—	0.8	0.7	0	0.7
Total weeds	—	0.4	2.5	8.3	0.8	4.0	1.9	7.5
Mixture VI								
Bare ground	—	—	1.8	0	3.8	1.5	0	0.6
Sown species, white clover	3	37.9	19.6	4.8	15.1	6.8	13.2	3.9
Sown species, Ky. bluegrass	8	27.9	42.0	60.7	60.4	58.6	62.6	71.0
Sown species, orchard grass	5	7.0	6.7	4.1	3.8	4.5	2.6	4.5
Sown species, timothy	4	9.6	4.0	0.7	0	0.8	0.9	0.6
Sown species, per. ryegrass	4	17.6	23.7	15.9	17.0	23.3	16.3	7.7
Volunteer grasses and legumes	—	—	—	—	0	1.5	1.3	—
Total weeds	—	0.1	2.2	13.8	0	3.0	3.1	11.8
Mixture VII								
Bare ground	—	—	3.6	0	6.0	1.6	0	0
Sown species, white clover	4	66.1	23.8	16.7	18.0	10.4	18.5	6.3
Sown species, Canada bluegrass	20	28.9	62.2	41.7	23.0	27.2	10.6	2.5
Volunteer grasses and legumes†	—	—	8.9	26.4	50.0	60.0	67.6	75.6
Total weeds	—	5.0	1.5	15.3	3.0	0.8	3.2	15.6
Mixture VIII								
Bare ground	—	—	1.1	0	5.0	2.0	0	0
Sown species, white clover	4	37.9	20.2	11.3	9.0	7.3	11.5	6.0
Sown species, colonial bent	20	60.8	75.1	78.0	73.0	72.0	61.2	41.7
Volunteer grasses and legumes†	—	—	2.0	4.8	13.0	14.7	26.3	45.1
Total weeds	—	1.3	1.6	5.9	0	4.0	1.0	7.3

*Average estimate of each species in each clipping.
†Mostly Kentucky bluegrass.

TABLE 3.—*Monthly, annual, and 4-year average yield of dry herbage from the plots sown to the eight pasture mixtures.*

Period	Average dry yields of the pasture mixtures in pounds per acre							
	I	II	III	IV	V	VI	VII	VIII
1937								
April and May	743	1,710	1,128	1,823	2,012	1,650	1,192	2,147
June	743	851	1,034	1,078	709	807	831	1,007
July	165	140	147	97	96	112	80	101
August	404	290	304	310	470	337	332	393
Sept. and Oct	1,244	1,152	1,112	1,152	1,384	1,229	1,381	1,268
Total	3,299	4,143	3,725	4,460	4,671	4,135	3,816	4,916
1938								
April and May	1,398	1,277	1,150	1,340	1,298	1,276	1,264	1,054
June	0	0	0	0	0	0	0	0
July	356	208	215	249	322	156	251	137
August	898	944	640	767	827	718	579	488
Sept. and Oct	527	467	349	459	462	325	594	433
Total	3,179	2,896	2,354	2,815	2,909	2,475	2,688	2,112
1939								
April and May	629	631	657	673	661	736	955	617
June	0	0	0	0	0	0	0	0
July	348	278	254	384	425	395	179	296
August	102	68	47	52	106	55	203	67
Sept. and Oct	476	400	192	309	403	307	350	203
Total	1,555	1,377	1,150	1,418	1,595	1,493	1,687	1,183
1940								
April and May	299	142	384	364	475	380	289	203
June	742	731	601	695	697	560	706	709
July	0	0	0	0	0	0	0	0
August	402	341	450	504	489	479	358	449
Sept. and Oct	407	467	359	422	439	462	387	421
Total	1,850	1,681	1,794	1,985	2,100	1,881	1,740	1,782
4-Year Average								
April and May	767	940	830	1,050	1,112	1,011	925	1,005
June	371	396	409	443	352	342	384	429
July	217	157	154	183	211	166	128	134
August	452	411	360	408	473	397	368	349
Sept. and Oct	664	622	503	586	672	581	678	581
Total	2,471	2,526	2,256	2,670	2,820	2,497	2,483	2,498

the 4-year period, 1937–40, and for the 53-year average are given in Table 5. The total annual production of pasture herbage is closely associated with the rainfall, the greatest production being in 1937 which is also the year of the greatest rainfall.

TABLE 4.—*Analysis of the 1937 and 1940 yields of the pasture mixtures.*

Source of variation	Degrees of freedom	1937 yields		1940 yields	
		Mean square	F	Mean square	F
Blocks	2	549,032.2	—	647,835.2	—
Mixtures	7	844,981.8	5.84*	43,941.7	3.00
Error	14	144,802.9	—	131,799.6	—

*Highly significant.

TABLE 5.—*Precipitation in inches during the pasture season at Beltsville, Md., 1937–40.*

Year	April	May	June	July	Aug.	Sept.	Oct.	Total for pasture season
1937	7.28	3.08	2.41	4.67	7.52	0.93	9.34	35.23
1938	0.99	3.17	0.86	5.23	4.02	3.60	1.69	19.56
1939	4.52	1.52	4.06	2.75	1.82	4.10	3.91	22.68
1940	5.97	3.76	0.57	3.15	2.99	4.35	3.33	24.12
53-year average*	3.42	3.53	4.02	3.92	4.41	3.21	2.70	25.21

*College Park, Md., data.

RESULTS AND DISCUSSION

BOTANICAL COMPOSITION OF THE MIXTURES

The estimates and botanical counts are averaged and given in Table 2. Rather than discuss all species of each mixture together, each species is considered separately and conditions affecting its increase or decrease in any particular mixture are given.

Louisiana white clover.—The average percentage of white clover in the cover of all mixtures declined from 40.7% in 1937 to 8.5% at the end of the second year, but while the decline continued during the remaining 2 years, the decrease was much less severe. The average percentage of white clover in the fourth year (Table 2) shows a slightly higher percentage in mixture with Kentucky bluegrass or Canada bluegrass than in the more complex mixtures or with Colonial bent. In general, the percentage of white clover was greater on those plots in which the rate of grass establishment was slow.

The Louisiana white clover is intermediate in growth characteristics between Ladino and the low-growing naturalized white clover. At the end of 4 years the type of clover present on the plots conformed closely to that of the naturalized white clover found in the older pastures in this region. The results indicate that either the white clover as seeded is a short-lived perennial and that naturalized white clover has come into the plots, or that only the smaller types present in the white clover seed as reported by Ahlgren and Sprague (1) have persisted during the 4-year period. In comparisons of the various white clovers seeded on old permanent pastures at this station, however, it has been noted that 3 to 4 years after seeding, the majority

of the white clover plants remaining on those plots seeded to Louisiana white or commercial white clover are indistinguishable from volunteer clover plants on adjacent unseeded plots, particularly under close grazing or clipping. The competition from grasses under conditions of close clipping and grazing, and the deleterious effect of summer drought undoubtedly reduced the percentage of Louisiana white clover in the cover of these plots over the 4-year period.

Kentucky bluegrass.—At the end of 2 years, Kentucky bluegrass predominated in all mixtures in which it was included. The greatest percentage of Kentucky bluegrass developed on those plots sown to this species in combination with white clover and in Mixture V which contained Italian ryegrass, orchard grass, and timothy. In this mixture Italian ryegrass functioned chiefly as a nurse crop to the pasture grasses, apparently favoring the establishment of Kentucky bluegrass more than orchard grass and timothy. The competition from perennial ryegrass in Mixture VI definitely retarded the spread of Kentucky bluegrass. The failure of orchard grass, redtop, and timothy to check appreciably the spread of Kentucky bluegrass may be attributed largely to two factors. First, as other workers have shown (2, 3, 8), stands of these three grasses are normally weakened by continued close clipping since they are more completely defoliated than Kentucky bluegrass, and second, the relatively high fertility level of the soil definitely favored the establishment and growth of Kentucky bluegrass. These or similar factors are considered responsible for the predominance of Kentucky bluegrass in old permanent pastures throughout the northern humid states.

Redtop.—The percentage of redtop in the pasture cover declined from year to year. At the end of the 4 years a significantly greater percentage of redtop was shown in those plots in which it was seeded in combination with Kentucky bluegrass than in the same mixtures with orchard grass or orchard grass and timothy. In this experiment, redtop was equal if not superior to orchard grass in persistence.

Orchard grass.—At the end of 4 years the percentage of orchard grass remaining in the cover was very low and showed no significant difference between mixtures. The depressing effect of Italian ryegrass on orchard grass as reported in Wales by Stapledon and Davies (9) was not apparent from these studies.

Timothy.—The percentage of timothy in the mixtures in which it was included declined from 10.8% in 1937 to less than 3.0% in 1938. At the conclusion of the 4 years, the percentages of timothy in all mixtures had declined to an insignificant level. It is apparent that timothy cannot persist in association with these grasses under the conditions of frequent clipping or close grazing.

Italian ryegrass.—Italian ryegrass made up a significant amount of the pasture herbage only during the early cuttings of 1937. As this species died out the percentage of Kentucky bluegrass rapidly increased. The development of orchard grass and timothy was not greatly benefited by the addition of the Italian ryegrass.

Perennial ryegrass.—This was the only grass, with the exception of Kentucky bluegrass, able to persist in a mixture in appreciable amounts longer than 2 years.

Canada bluegrass.—The results with Canada bluegrass indicate its inability to persist in competition with other grasses under close cutting or grazing and at a relatively high fertility level. This species was gradually replaced by Kentucky bluegrass. The percentage of Canada bluegrass declined from 62.6% in April 1938 to less than 5% in October 1940.

Colonial bent.—The mixture of colonial bent and white clover was very productive the first year. Kentucky bluegrass, however, began coming into the sward in the second year and at the end of 4 years composed over 50% of the grass cover.

Weeds.—The plots seeded to a mixture of Canada bluegrass and white clover contained slightly more weeds than did the plots of the other mixtures. The weed content of the plots of the other mixtures were not significantly different.

In presenting the data no attempt is made to divide the weed percentages into annual and perennial species. It will be noted in Table 2 that the percentage of weeds in the fall readings was usually much higher than in the spring or early summer. Fully 90% of the weed species recorded in the fall readings was crabgrass (*Digitaria sanguinalis* Scop.). The weed species noted in the spring and summer were largely perennial and included dandelion (*Taraxacum officinale* Weber), plantain (both *Plantago lanceolata* L. and *P. major* L.), sheep sorrel (*Rumex acetosella* L.), and wild garlic (*Allium vineale* L.).

YIELDS

During the first year of the experiment the total yields of the various mixtures were significantly different according to the analysis of variance of the data (Table 4). Mixtures IV, V, and VIII composed of white clover in combination with (IV) Kentucky bluegrass, redtop, orchard grass, and timothy; (V) Kentucky bluegrass, orchard grass, timothy, and Italian ryegrass; and (VIII) colonial bent were the most productive. The greater productivity of these mixtures in this first year (Table 3) occurred during the months of April, May, and June. The yields of the mixtures during 1938 and 1939 were not greatly different and certainly were no higher than the simple mixture of Kentucky bluegrass and white clover. The yields of 1940 were also analyzed for significance, but showed no superiority in yield of the various mixtures during that year.

From a consideration of the seasonal productivity of the mixtures (Table 3), it is at once apparent that herbage production during July and August also has not been appreciably altered by the various mixtures, however complex.

During the first year of the experiment, a year of above normal rainfall, the mixture of colonial bent and white clover was very productive. In subsequent years, however, under less favorable climatic conditions the yield of this mixture was consistently lower than the mean yield of all mixtures.

In general, the results of this experiment indicate that at a relatively high fertility level, the complex permanent pasture mixtures may be more productive than a simple mixture of Kentucky bluegrass

and white clover in only the first and possibly the second year after seeding. The length of the period of greater production of the complex mixtures will be dependent upon the rate of establishment of Kentucky bluegrass.

CONCLUSIONS

A series of eight pasture mixtures composed of various grass species in association with Louisiana white clover have been tested over a 4-year period at Beltsville, Md.

The percentage of Louisiana white clover declined rapidly through the early years of the experiment, indicating its inability to persist in competition with grasses under close cutting.

Kentucky bluegrass predominated at the end of the second year after seeding in all mixtures in which it was included. It comprised over 90% of the total grass population in these mixtures the fourth year.

The percentages of orchard grass, timothy, and redtop decreased as the experiment progressed with timothy being the least persistent. In the fourth year the amounts of these species were small and affected the yield of herbage very little.

The use of more complex seed mixtures for permanent pasture increased the yield of herbage significantly only in the first year after seeding and only during April, May, and June of that year. Herbage production during July and August was not increased regardless of the complexity of the mixture sown.

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DISEASE RESISTANCE OF *TRITICUM TIMOPHEEVI* TRANSFERRED TO COMMON WINTER WHEAT[1]

R. G. SHANDS[2]

TRITICUM timopheevi Zhuk. is a species native to southern Russia and was introduced into this country by the U. S. Dept. of Agriculture in 1930. It is an unusual wheat because of its resistance to a number of diseases and because species crosses with it are highly sterile. It has proved highly resistant to leaf rust and stem rust under field conditions for the past 9 years at Madison, Wis. Several tests during this period indicate that it is resistant to bunt and mildew. It offers a new source of disease resistance which should be very valuable to the plant breeder if transferred to the common wheats. Rust resistance factors from other 14-chromosome wheats have been valuable in recently produced varieties of common wheat. Iumillo durum was the source of rust resistance in Thatcher and Yaroslav emmer for that in Hope which, in turn, has been used extensively in breeding new varieties. Investigations of Kihara and Lilienfeld[3] and of Kostoff[4] have shown that hybrids between *T. timopheevi* and other *Triticum* species are highly self-sterile regardless of chromosome number of the species used. From the cross *T. vulgare* Vill. variety Steinwedel × *T. timopheevi*, Pridham[5] obtained lines that were resistant to stem rust and leaf rust and *T. vulgare* in type.

This paper briefly gives the history of a hybrid, its fertile progeny, and a few preliminary karyological observations. Crosses were made between *Triticum timopheevi* and a number of varieties of *T. vulgare*, the haploid chromosome numbers being 14 and 21, respectively. Difficulty was experienced in obtaining germinable hybrid seed when *T. timopheevi* was used as the female. The kernels developed to a normal size at the milk stage, but at maturity they were very shrivelled and most of them failed to germinate. There was no difficulty, however, in obtaining seed when *T. vulgare* was used as the female. The hybrid caryopses were smaller than normal for the female parent but were relatively plump with a visible and viable embryo. The first generation plants were highly self-sterile in all crosses. Thus, approximately 6,600 selfed flowers from F_1 plants of all crosses have produced only 23 kernels, or 0.348% fertility. The anthers dehisced poorly and the iodine test showed about 95% of the pollen grains apparently sterile. Emasculating the F_1 plants and pollinating with *T. vulgare*

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the College of Agriculture, University of Wisconsin, Madison, Wis. Received for publication March 21, 1941.

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pollen has, however, resulted in a self-fertile progeny as described below.

The first crosses from which fertile hybrids have been secured were made in 1933. A spring selection from a hybrid of Illinois No. 1 and Chinese was used as the female and *Triticum timopheevi*, P.I. 94761,[6] was used as the male. Two F_1 plants were grown in 1934. Fifty of the heads were entirely self-sterile. A few heads were emasculated and covered with glassine bags and later pollinated with pollen of *T. vulgare* variety Wisconsin Pedigree No. 2. Three F_1 plants from this back cross grown in 1935 produced only one selfed kernel from a total of approximately 1,500 flowers. In 1935–36, this kernel produced a completely fertile, vigorous, winter-type F_2 plant. The F_3 population from this plant was grown in the field in six rows, 10 feet in length, in 1936–37. A good stand was obtained, but winter-killing, caused by an ice sheet, greatly reduced the stand and only 16 plants survived. These plants were fertile and very vigorous with many tillers. They were attacked to some extent by leaf rust. Under the heavy natural epidemic of stem rust, a few of the plants had a trace while others remained free. The F_4 generation was grown in 1937–38 as progenies of the 16 plants. Segregation for reaction to stem rust and leaf rust and for morphologic type occurred. The population was selected for the best available resistance to the rusts and the plants were bulked as progenies of the 16 F_3 plants. The F_5 generation of each of the 16 bulks was grown in 5 to 10 rod rows in 1938–39 at which time further mass selection was made for leaf rust resistance. Also, a number of single plants were selected. The F_6 generation was grown in 1939–40 again as 16 bulks in 10 rod rows each. In addition a few sub-bulks with resistance to leaf rust or mildew, or both, were grown. A severe epidemic of stem rust developed and susceptible plants were removed. Over 400 plant selections were also grown in 1939–40 and 35 of these proved to be homozygous susceptible for stem rust reaction and 26 were heterozygous. The remaining rows appeared to be homozygous for resistance, being free of stem rust or having only a trace. Although the leaf rust epidemic was not severe enough in 1940 to give wide differences in infection, a small number of rows appeared to be resistant to both rusts.

Tests are in progress to determine the bunt reaction as well as loose smut reaction of lines selected in the F_5 generation. Additional plants were selected in the F_6 generation for agronomic characters and disease resistance.

Several morphological characters of the *Triticum timopheevi* parent have appeared in the hybrid populations such as long hairs on leaves, pubescent glumes, pubescent nodes, brittle heads at maturity, and very dense or club-like heads. Plants with awnless lemmas, or with beaks nearly as long as the awns, or with an extra glume between the outer glume and lemma have been observed. These latter characters do not exist in any of the three parents. Although there is a wide range in segregation for morphological types, the population varies in appearance around those types commonly associated with

[6]P.I. refers to the accession number of the Division of Plant Exploration and Introduction, formerly Foreign Plant Introduction.

T. vulgare, except for the characters just noted. All lines and bulk populations thresh easily with no tendency of glume adherence which is typical of *T. timopheevi*.

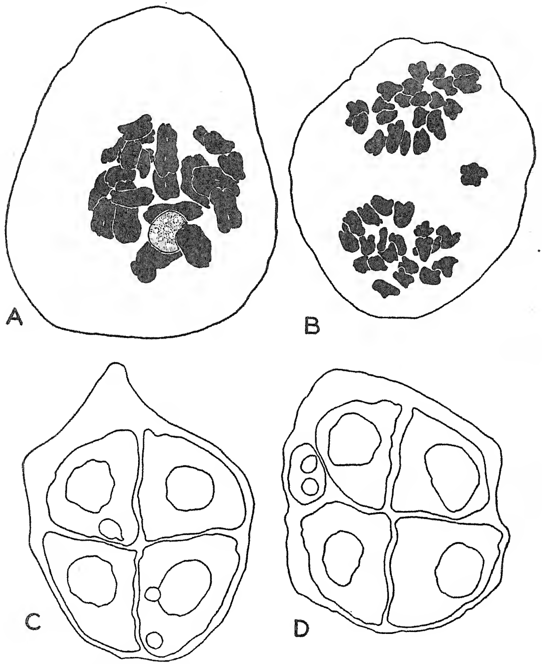

FIG. 1.—A, pollen mother cell from an F_1 plant (Marquis×H143-1-1-4-27) at diakinesis, showing 21 pairs of chromosomes; B, pollen mother cell from an F_1 plant (Marquis×H143-1-1-15-54) at anaphase I, showing a lagging chromosome; C, tetrad from an F_1 plant (Marquis×H143-1-1-15-54), showing nuclei and micronuclei; D, "tetrad" from an F_1 plant (Marquis×H143-1-1-15-54), showing two micronuclei walled off as a fifth microspore. All ×900.

The bulk population, as well as the plant lines, tends to be later in maturity than common winter wheat varieties, but a few have approximately the same maturity date as the Wisconsin Pedigree No. 2

(Turkey type) parent. The selections have the winter habit of growth, although *Triticum timopheevi* has a late spring habit of growth. A few of the lines were winterkilled but a number appear to be as hardy as the Wisconsin Pedigree No. 2. A number of the lines have good agronomic appearance and indications of good yielding capacity. All lines appear to be completely fertile and produce viable kernels that are normal in size.

Aceto-carmine smears of root tips from four of the plant lines representing different bulks showed 42 somatic chromosomes. A number of plant lines were used as pollen parents in crosses with several varieties of common wheat in 1940. The percentage of flowers setting kernels was high and kernels were normal in size and plumpness.

F_1 plants from the hybrids between Marquis (female) and six plant lines representing different bulks were grown in the greenhouse in 1940–41. Aceto-carmine smears of pollen mother cells from them showed n as 21 or $2n$ as 42 chromosomes (Fig. 1, A). At diakinesis, three of the hybrids showed normal synapsis, giving 21 pairs. Another frequently showed one or more lagging chromosomes (Fig. 1, B) during the anaphase of the first division and in some of the cells the lagging chromosomes apparently failed to reach the poles prior to the telophase. After the second division, microspores were frequently observed with one to three micronuclei (Fig. 1, C). Sometimes the micronuclei were surrounded by a cell wall giving a fifth microspore (Fig. 1, D). Another hybrid showed occasional microspores with micronuclei. This condition was comparatively rare in the Marquis parent. Pollen from mature anthers of all hybrids showed a higher percentage of sterility than Marquis. Approximately 80% of the flowers set kernels when the hybrids were allowed to self-pollinate under greenhouse conditions of the late winter. Presumably they would be completely fertile under favorable field conditions. The hybrid with lagging chromosomes was about 55% self-fertile under the same greenhouse conditions.

These results indicate that a number of *Triticum timopheevi* characters, including resistance to mildew, leaf rust, and stem rust, have been transferred to fertile types of *T. vulgare* winter wheat and, furthermore, that several of these plant lines are fertile in hybrids with other varieties of common wheat.

FIELD MEASUREMENTS OF WATER MOVEMENT THROUGH A SILT LOAM SOIL[1]

N. E. Edlefsen and G. B. Bodman[2]

A KNOWLEDGE of the rate at which water moves through undisturbed soils after they have been wetted is of much significance in practical agriculture as well as in engineering problems concerned with soil mechanics and underground water. Many investigations have been made for the purpose of measuring the amount of water stored in field soils after being wetted. So far as the authors know, however, no long-continued sequence of measurements, in which evaporation and transpiration were prevented, has been made on undisturbed soil for the purpose of determining the magnitude of the vertical flow across various horizontal planes. The experiment here reported had this as its principal objective.

Israelsen and West (4)[3] have published results from plots which had been heavily irrigated and covered with straw to retard evaporation. Their two sets of measurements indicated a comparatively rapid movement immediately following irrigation.

Veihmeyer and Hendrickson (7), working in the Sacramento Valley where no rain fell during the growing season, presented the results of wetting to about 6 feet a soil which had been previously dried by a grain crop. Under these conditions, there was present at all times a zone of dry soil below that wetted by the irrigation. No plants were allowed to grow after irrigation. They found very little movement during the interval between the fifth and sixty-first day after irrigation.

Blaney, Taylor, and Young (1) reported a series of moisture records on a plot of ground which had been irrigated and then covered to prevent evaporation. The tests were made over a period of 14 months and indicated a decreasingly slow downward movement during this period.

Several experiments have been conducted by the authors since 1932 with soils on the University Farm at Davis, Calif., to determine their behavior, *in situ*, with respect to downward water movement after irrigation. The present results are representative of these experiments and have the advantage of accumulation over a longer continuous period upon a more uniform soil type than any of the other experiments which were undertaken. They were carried out on a silt loam soil of the Yolo series during a period of 842 days from October 1934 to January 1937.

The Yolo series consists of recent, secondary soils which have formed upon deep, valley sediments derived from sandstones and shales. They lack the conspicuous horizon differentiation associated

[1]Contribution from the California Agricultural Experiment Station, Berkeley, Calif. Received for publication March 25, 1941.

[2]Associate Professor of Irrigation and Associate Irrigation Engineer in the Experiment Station and Professor of Soil Physics and Soil Physicist in the Experiment Station, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 731.

with highly-developed soil profiles and, in general, are comparatively uniform in texture and structure throughout their mass. They are frequently more or less stratified in their deeper layers owing to the occurrence of varying conditions during the original deposition of the soil material. In all of these respects the Yolo soils represent extensive areas of the valley soils in California and are among the most productive in the Sacramento Valley.

DESCRIPTION OF METHOD

The particular plot used in this experiment was part of a field upon which barley had been grown for several years. It was selected for the study because of its intermediate and relatively uniform texture to a depth of many feet and its convenient location on University Farm at Davis.

The plot itself consisted of a level, square, area, 16 feet by 16 feet, which was surrounded and defined by a low earth dike. The plot was undisturbed by the construction of the dike, the inner faces of which consisted of lengths of 1- by 12-inch board, set on edge.

Irrigation water was applied in an amount more than sufficient to saturate the entire soil mass down to the water table which, during the experiment, was always at a depth of more than 22 feet from the soil surface. The rate at which the water sank into the ground was measured by means of a hook gauge. When the water was first applied its rate of entry into the soil was rather high. The entry rate slowly diminished, however, and finally became uniform. The uniform rate was recorded as the rate of downward movement at zero time. The zero of time (t_0) for all subsequent calculations of moisture content or velocity was counted as the time at which the free water surface coincided with the surface of the ground.

At zero time the plot was covered with heavy roofing paper with a good overlap upon which was brushed hot tar. Another layer of roofing paper was then applied so as to overlap the joints of the first layer. Plank bridges, resting upon the dike at each side, were placed across the plot during these operations in order to preserve the soil surface undisturbed. A 6-inch layer of very finely screened, mixed, dry soil was spread above the two layers of roofing paper and finally a sheet-iron roof was built over the entire area to keep out rain. During the course of the experiment all plant growth was prevented for a distance of 4 feet from the dikes at the edge of the plot, and the field surrounding the plot remained in a fallow condition.

An area 8 feet by 8 feet, lying in the middle of the plot, was chosen for periodic soil sampling for moisture determinations. A guard strip, 4 feet in width, was thus left on each side. The samples were taken with a standard soil tube by depths of 6 inches to a maximum depth of 9 feet. The volume of soil under treatment may, therefore, be considered as a roughly rectangular column 256 square feet in cross-sectional area and approximately 22 feet in depth. The soil under investigation, on the other hand, comprised a rectangular, inner column, well guarded from border effects, 64 feet in cross-sectional area and 9 feet in depth.

A systematic plan of sampling was devised and followed throughout. The inner, sampling area was subdivided into four quarters, A, B, C, D, as shown in Fig. 1. Each quarter was again divided into nine equal, smaller areas. Upon each sampling date, 18 samples of soil, taken by 6-inch sections one below the other to a depth of 9 feet, were withdrawn by means of the soil tube from each of four holes, made one in each of the quarters A, B, C, or D. The first set of samples, taken 3 days after zero time, was drawn from the small squares 1a in each of the four

quarters. It consisted of 72 samples, composed of four lots of 18, each lot taken from the area A-1a, B-1a, C-1a, or D-1a. The second set of 72 samples, taken 6 days after zero time, was withdrawn from areas A-1b, B-1b, C-1b, and D-1b. The entire sampling series progressed over the plot in this way in the sequence: 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c, 1a. The tenth set, which was taken 842 days after zero time, consisted, as may be seen, of four lots of samples taken for a second time from areas A-1a, B-1a, C-1a, and D-1a. Care was taken that the exact sampling positions for the tenth set were well removed from those of the first set. Each area is labelled in Fig. 1 by a small t with a subscript number which

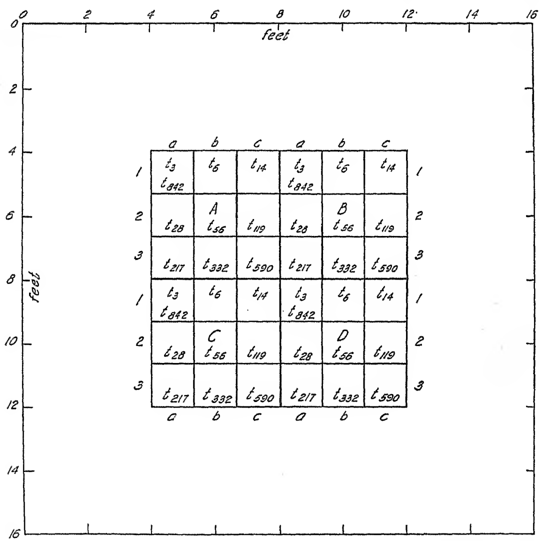

FIG. 1.—Diagram of plot used in experiment on penetration of water under field conditions, showing divisions of plot and sequence of sampling.

represents the time in days, counting from zero time, at which the samples from that area were taken. The proper sampling positions were determined at the time of collection by strings stretched across the plot between fixed markers on the dike. The samples were collected very carefully and the water content of each was determined by drying at a temperature of 110° C.

Certain physical properties of the soil in the experimental plot are presented in Figs. 2 and 3. Fig. 2 represents the mechanical analysis of the surface foot of soil

in the form of a summation curve in which mean effective diameter is shown along the axis of abscissas and summation percentage (percentage finer than) is given on the axis of ordinates. The analysis was made by the pipette method with a representative sample of the fine earth which had been dispersed by pretreatment with hydrogen peroxide and hydrochloric acid after which it was washed and shaken overnight with sodium oxalate solution.

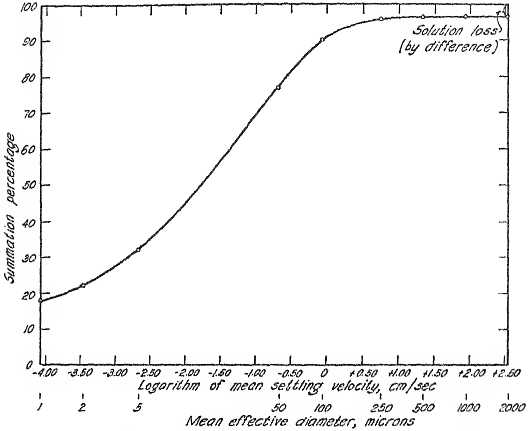

FIG. 2.—Mechanical analysis of soil taken from surface foot of the plot.

Fig. 3 presents, in left and right halves respectively, the apparent density and moisture equivalent in relation to depth from surface by 6-inch layers. The apparent density measurements were made after all other sampling had been completed. It was desired to obtain a highly representative set of values for apparent density for the entire column of soil since knowledge of this variable is essential to the calculation of the velocity of water movement. After consideration of numerous possible methods, it was at last decided to excavate, with as much accuracy as the technic permitted and to the full depth of 9 feet, a succession of rectangular blocks of soil one immediately below the other, each consisting of a volume 1 square foot in cross-section by 6 inches in height. This was accomplished with the help of plumb-bob, builders' square, straight edge, spade, and trowel, the soil from each block being removed without loss to a tight sack in which it was taken to the laboratory for thorough mixing, weighing, and moisture-content determinations. A narrow trench, 12 feet deep, was first dug for the purpose directly across the middle of the plot from north to south, and the apparent density samples were excavated in the middle of the opposite walls. The curves labelled E, W, and M, respectively, represent the results, with their means, for

the two sets of such blocks of soil which were removed from the eastern and western halves of the central part of the inner plot.

Soil samples for measurement of the moisture equivalent were taken by tube from two opposite halves of the plot and the determination was made in the usual way. The separate results and their means are shown by curves A, B, and C, respectively. It is believed that the moisture equivalent maxima which occur at

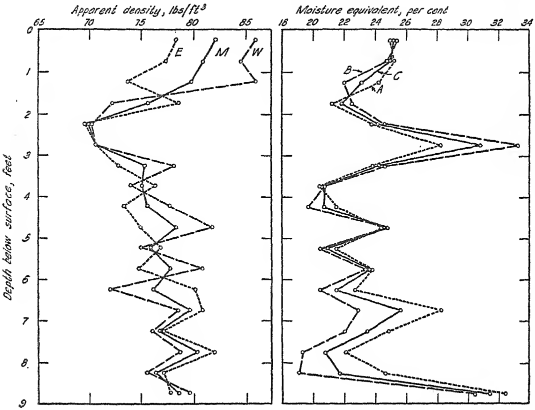

FIG. 3.—Apparent density in pounds per cubic foot and moisture equivalent percentage for each 6-inch layer of the plot to a depth of 9 feet.

depths between 30 and 36 inches from the soil surface represent peculiarities of deposition rather than the development of a B horizon, and that the fluctuations in density and moisture equivalent in this soil column are in all cases attributable to such peculiarities.

EXPERIMENTAL RESULTS

Table 1 presents the entire series of moisture contents expressed as percentage by weight, dry basis, and as inches for all depths at various times of sampling. It contains, in addition, the mean moisture equivalents and mean apparent densities, layer by layer, as well as the moisture contents of the soil for all depths at zero time. The moisture contents at zero time are of necessity indirectly calculated results, owing to the impossibility of satisfactorily sampling the soil for moisture determinations immediately after free water had disappeared from the soil surface. The moisture contents at zero time depend upon the calculation of total pore space from real and apparent density. The real density of the soil was assumed equal to 2.65 gms/cc; the apparent densities, as previously explained, were directly measured.

It was further assumed that, at zero time, all soil pores were completely occupied by water. This assumption represents a close approximation to the truth, although it is doubtful that absolute saturation was obtained. Each entry for water content, after zero time, represents an average of four individual measurements from the four quarters, A, B, C, and D, of the plot. Table 1 contains the basic data from which the values given in the remaining tables, as well as the values used in the following graphs (except Fig. 9 which includes vapor pressure and surface tension gradients) can be calculated.

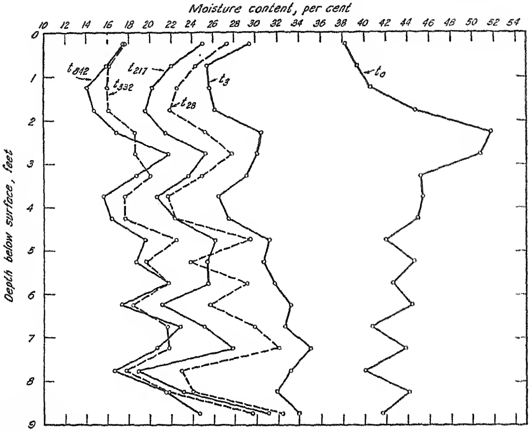

FIG. 4.—Variation in moisture content with time and depth.

The significance of the data of Table 1 may be more easily understood by reference to Fig. 4 which is designed to indicate the general trend of changes in soil-moisture content with time. Only certain of the sampling dates are represented in the graph for the sake of greater clarity. The curves are labelled so as to indicate the dates of sampling. For example, t_{28} means that the moisture content has been determined for soil samples obtained on day 28 after zero time. A slow downward movement of water through the soil mass is indicated by the gradual shift of the moisture content-depth curve toward the left as time progressed.

The term *field capacity* is used in irrigation practice to define that moisture content for a given soil below which downward motion of water is negligible in comparison with the rate at which growing plants extract water from the soil. It is not a specific value. The

moisture equivalent is frequently used as an indirect measure of the field capacity of agricultural soils and the term relative wetness is used to define the ratio of the moisture content to the moisture equivalent. In other words, when the relative wetness of most soils is unity, they are considered to be at their field capacity. Calculations of relative wetness values for all samples from the experimental plot have some significance, therefore, and the results are presented in Table 2 as a function of time and depth during the period of the experiment.

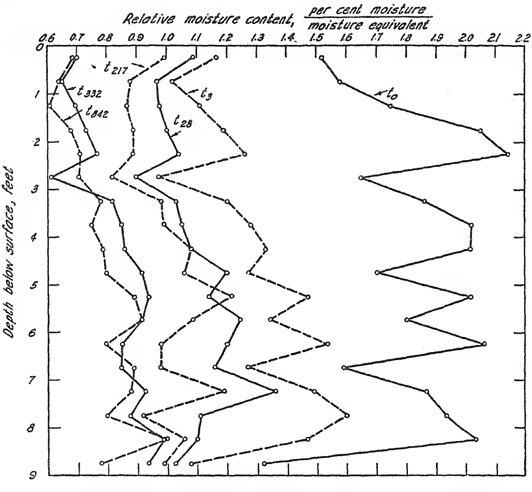

FIG. 5.—Variation in relative moisture content with time and depth.

The change in relative wetness with depth at various times is shown in Fig. 5. Evidently the water moves out of the soil at moisture contents much below the moisture equivalent even in the lower depths. Two months had elapsed, however, before the soil at any depth had lost water in quantities sufficient to produce a relative wetness which was significantly below 1. It is evident that if plants were growing on this soil the rate of extraction by the plants would be high as compared with the rate of downward movement when the relative wetness is less than 1, that is, during the time period 58 to 842 days.

The change in average relative wetness with time for the upper and

TABLE 1.—*Variation in moisture content as percentage, and as inches with depth and time.**

Date				1934						1935			1936	1937
				Oct. 3	Oct. 6	Oct. 9	Oct. 17	Oct. 31	Nov. 30	Jan. 30	May 8	Aug. 31	May 15	Jan. 22
No. of days after t_o				0	3	6	14	28	58	119	217	332	590	842
Depth, ft. or in.	Moisture equivalent	Apparent density, gm/cc												
0–6	—	1.315	%	38.31	29.48	28.11	27.33	27.31	25.70	25.02	25.02	17.60	16.90	17.55
0–0.5	25.12	—	in.	3.023	2.326	2.218	2.156	2.155	2.028	1.974	1.974	1.389	1.333	1.385
6–12	—	1.296	%	39.42	25.36	26.34	25.05	24.34	22.95	22.45	22.06	16.20	15.50	16.05
0.5–1	24.96	—	in.	3.066	1.972	2.048	1.948	1.893	1.785	1.746	1.715	1.260	1.205	1.248
12–18	—	1.277	%	40.57	25.65	24.85	23.95	22.54	21.13	20.27	20.19	16.00	15.20	14.18
1–1.5	23.13	—	in.	3.109	1.965	1.904	1.835	1.727	1.619	1.553	1.547	1.226	1.165	1.086
18–24	—	1.211	%	44.84	26.12	24.91	22.34	21.92	18.47	19.64	19.56	16.10	14.50	14.83
1.5–2	21.88	—	in.	3.258	1.898	1.810	1.623	1.593	1.342	1.427	1.421	1.170	1.054	1.078
24–30	—	1.118	%	51.71	30.46	28.96	26.22	25.19	22.49	21.79	21.42	18.70	17.40	16.95
2–2.5	24.14	—	in.	3.469	2.043	1.943	1.759	1.690	1.509	1.461	1.437	1.254	1.167	1.137
30–36	—	1.130	%	50.76	30.14	29.42	28.92	27.79	25.70	27.30	25.35	18.70	25.60	21.83
2.5–3	30.80	—	in.	3.442	2.043	1.995	1.961	1.884	1.742	1.851	1.719	1.268	1.736	1.480
36–42	—	1.206	%	45.18	29.22	27.12	26.47	25.04	24.00	23.54	23.72	20.00	20.20	18.85
3–3.5	24.24	—	in.	3.269	2.114	1.962	1.915	1.812	1.737	1.703	1.716	1.447	1.462	1.364
42–48	—	1.203	%	45.39	26.46	23.77	22.34	21.71	19.69	19.40	20.58	17.70	17.20	15.63
3.5–4	20.71	—	in.	3.276	1.910	1.716	1.613	1.567	1.421	1.400	1.485	1.278	1.241	1.128

48–54	—	1.210	%	44.91	27.47	26.11	24.21	22.40	23.12	21.73	22.40	17.70	24.90	16.43
4–4.5	20.65	—	in.	3.260	1.994	1.896	1.758	1.626	1.679	1.578	1.626	1.285	1.808	1.193
54–60	—	1.254	%	42.01	31.25	28.68	29.00	29.48	24.94	26.66	26.07	22.50	20.00	19.63
4.5–5	24.54	—	in.	3.161	2.351	2.158	2.182	2.218	1.876	2.006	1.962	1.693	1.505	1.477
60–66	—	1.214	%	44.64	30.68	31.93	27.20	23.83	24.14	22.38	25.33	19.60	22.40	18.60
5–5.5	20.92	—	in.	3.251	2.235	2.326	1.981	1.736	1.758	1.630	1.845	1.428	1.632	1.355
66–72	—	1.245	%	42.59	31.75	30.68	29.33	29.19	24.30	26.72	25.55	21.80	22.00	21.75
5.5–6	23.60	—	in.	3.181	2.372	2.292	2.191	2.180	1.815	1.996	1.909	1.628	1.643	1.625
72–78	—	1.218	%	44.37	33.18	30.20	27.05	25.69	25.19	20.88	21.10	18.30	18.80	17.27
6–6.5	21.53	—	in.	3.242	2.425	2.207	1.977	1.877	1.841	1.526	1.542	1.337	1.374	1.262
78–84	—	1.275	%	40.70	32.59	33.35	31.58	29.80	26.37	26.05	25.15	21.70	23.50	22.93
6.5–7	25.58	—	in.	3.113	2.493	2.551	2.416	2.280	2.017	1.993	1.924	1.660	1.798	1.754
84–90	—	1.227	%	43.77	34.99	37.22	32.98	32.01	28.80	29.26	27.85	21.90	22.70	20.67
7–7.5	23.45	—	in.	3.222	2.576	2.740	2.428	2.357	2.120	2.154	2.050	1.612	1.671	1.522
90–96	—	1.286	%	40.02	33.21	32.54	25.50	23.08	22.61	20.51	18.95	17.80	17.20	16.65
7.5–8	20.68	—	in.	3.088	2.562	2.511	1.968	1.781	1.745	1.583	1.462	1.373	1.327	1.285
96–102	—	1.222	%	44.10	31.87	29.66	26.42	23.98	24.60	22.14	23.13	21.50	18.60	21.75
8–8.5	21.72	—	in.	3.233	2.337	2.175	1.937	1.758	1.804	1.623	1.696	1.576	1.364	1.595
102–108	—	1.259	%	41.70	34.01	34.58	32.03	32.38	30.91	31.20	31.08	29.70	27.80	24.65
8.5–9	31.47	—	in.	3.150	2.569	2.612	2.420	2.446	2.335	2.357	2.348	2.244	2.100	1.862

*Each value for a given depth and date represents the mean of four borings. (See plot diagram, Fig. 1.) All figures giving depth of water are based on an assumed horizontal homogeneity in the soil mass. For convenience in calculation, more digits have been retained for the entries in this table than are justified by the accuracy of the experimental work. It is believed that not more than three significant digits are justified, and, for that reason, the final results for average velocities in Table 3 are reported to three significant digits only.

TABLE 2.—*Variation in relative moisture content (total moisture percentage/moisture equivalent percentage) with depth and time.**

Date	1934						1935			1936	1937
	Oct. 3	Oct. 6	Oct. 9	Oct. 17	Oct. 31	Nov. 30	Jan. 30	May 8	Aug. 31	May 15	Jan. 22
No. of days after t_o	0	3	6	14	28	58	119	217	332	590	842
Depth, feet*											
0–0.5	1.522	1.174	1.119	1.088	1.087	1.023	0.9960	0.9960	0.7006	0.6728	0.6986
0.5–1	1.579	1.016	1.055	1.004	0.9751	0.9194	0.8994	0.8837	0.6490	0.6209	0.6430
1–1.5	1.754	1.109	1.074	1.036	0.9794	0.9135	0.8763	0.8728	0.6917	0.6571	0.6150
1.5–2	2.049	1.194	1.138	1.021	1.002	0.8441	0.8976	0.8839	0.7358	0.6627	0.6777
2–2.5	2.142	1.262	1.200	1.086	1.044	0.9317	0.9027	0.8873	0.7747	0.7208	0.7072
2.5–3	1.648	0.9786	0.9552	0.9390	0.9023	0.8344	0.8864	0.8231	0.6071	0.8312	0.7088
3–3.5	1.864	1.205	1.119	1.093	1.033	0.9900	0.9710	0.9785	0.8250	0.8333	0.7776
3.5–4	2.192	1.278	1.148	1.079	1.048	0.9508	0.9368	0.9938	0.8547	0.8306	0.7548
4–4.5	2.175	1.330	1.265	1.173	1.085	1.120	1.052	1.085	0.8572	1.206	0.7957
4.5–5	1.712	1.273	1.165	1.182	1.201	1.016	1.086	1.062	0.9169	0.8150	0.7999
5–5.5	2.134	1.467	1.526	1.300	1.139	1.154	1.070	1.211	0.9369	1.071	0.8891
5.5–6	1.805	1.345	1.300	1.243	1.237	1.030	1.132	1.083	0.9237	0.9322	0.9216
6–6.5	2.061	1.541	1.403	1.257	1.193	1.170	0.9699	0.9801	0.8500	0.8733	0.8022
6.5–7	1.591	1.274	1.304	1.235	1.165	1.031	1.018	0.9831	0.8483	0.9186	0.8963
7–7.5	1.866	1.492	1.587	1.406	1.365	1.228	1.248	1.188	0.9338	0.9679	0.8814
7.5–8	1.935	1.606	1.574	1.233	1.116	1.093	0.9919	0.9164	0.8608	0.8318	0.8052
8–8.5	2.030	1.467	1.366	1.216	1.104	1.133	1.019	1.065	0.9899	0.8563	1.001
8.5–9	1.325	1.081	1.099	1.018	1.029	0.9823	0.9915	0.9877	0.9439	0.8835	0.7834

*See footnote to Table 1.

lower 4½-foot sections is shown in Fig. 6. Both Figs. 5 and 6 indicate clearly that the relative wetness increases with increasing distance from soil surface at any given time. This is to be expected for a uniform soil. Variations from this rule occur in layers where there is a marked departure from the mean moisture equivalent.

For some purposes it is useful to have a picture of the change in the total quantity of water present, expressed in inches, in a section of soil of given depth, and to observe how this quantity changes with time. Fig. 7 has accordingly been prepared and shows, during the course of the experiment, the inches of water present in the soil sections 0–9 feet, 0–8 feet, 0–6 feet, 0–4 feet, and 0–2 feet. It will be noticed that a very rapid downward motion takes place for about the first 5 days. During the succeeding 55 days the downward velocity seems to be much greater in the lower depths than it is nearer the surface. The graph suggests a gradual decrease with time in the total amount of water in any given layer even to the end of the experiments. Attention is called, however, to some irregularities which appear in the data and which will be later discussed in more detail. The downward movement is greater during the interval 220 to 330 days than it is during a like interval of time either immediately preceding or following it. It should be noted also that the total water content of the soil in some of the layers at 590 days is slightly greater than it was at 330 days or at 840 days.

The moisture content, time, and apparent density[4] data of Table 1 made possible the calculation of the average flow density, or average velocity, $\frac{\Delta h}{\Delta t}$, across any given horizontal plane in the soil column. It should be noted that the flow density is here averaged with respect to time and also with respect to total area normal to direction of flow. No water was lost from the plot by evaporation or transpiration and none was added to the plot. Calculation of the average rate of vertical flow during a certain time interval can be made, therefore, by observing changes in the depth of water, h, in the soil above any given plane during the time concerned. If P_w represents the moisture content as percentage by weight, dry basis, present in any 6-inch layer of soil at any particular time, and if D represents the corresponding apparent specific gravity, then $0.06 \cdot P_w \cdot D = h$, where h now specifically represents the inches (depth) of water in the 6-inch layer of soil concerned. It is evident that the summations for a given time of the various values of h, previously calculated from the appropriate data for each of the 6-inch sections of soil in order from the 1st to the nth section from the surface, will provide the total inches (depth) of water lying above that plane which is defined by the lower surface of the nth soil section. This may be stated algebraically,

$$h_{t_x} = \sum_{1}^{n} [h]_{t_x}$$

[4]The apparent density and apparent specific gravity may be considered numerically equal in the C.G.S. system for the purpose of these calculations.

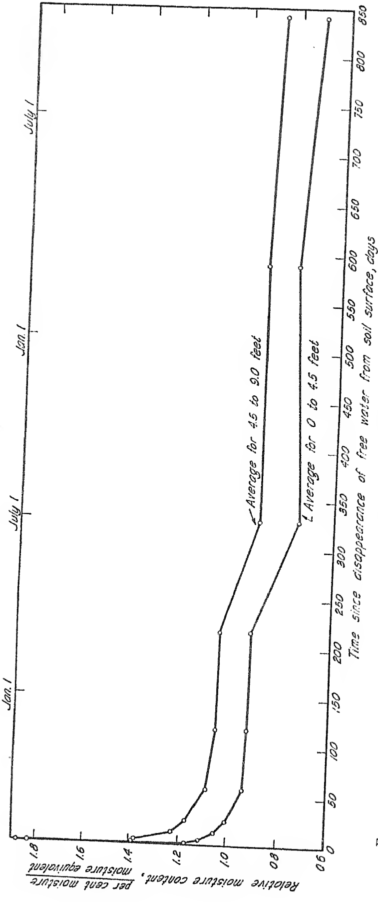

FIG. 6.—Average relative moisture content for the sections of soil from 0 to 4.5 feet and from 4.5 to 9 feet deep in relation to time.

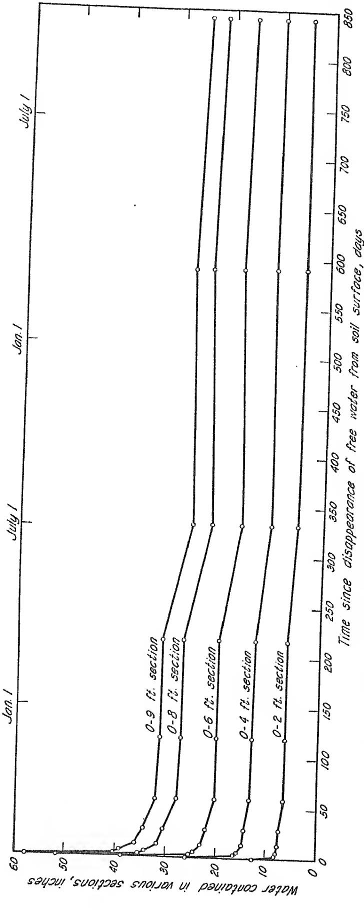

FIG. 7.—Inches in depth of water contained in different sections of soil in relation to time.

where h_{t_x} gives the total inches of water in all 6-inch soil sections from 1 to n at time t_x. If, now, similar calculations are made for a later time, t_y, the difference $h_{t_x}-h_{t_y}=\Delta h$ represents the total quantity of water which has passed across the plane at the bottom of the nth soil section during the time interval, t_y-t_x; hence the average vertical velocity during the time interval Δt is given by

$$\frac{\Delta h}{\Delta t}=\frac{h_{t_x}-h_{t_y}}{t_y-t_x}=\frac{\sum_{1}^{n}[h]_{t_x}-\sum_{1}^{n}[h]_{t_y}}{t_y-t_x}.$$

This arrangement of the equation yields positive velocities for downward movement.

Calculations of average velocities according to this equation were made for the entire period of the experiment and for all 6-inch sections to the full depth of 9 feet. They are presented in Table 3. The values in the body of the table represent average depths of water, expressed as inches per day, crossing various soil planes during those intervals of time which are entered in the head of the table.

Values for the flow density across the 3-, 6-, and 9-foot planes have been selected from Table 3 and are presently graphically in Fig. 8. Since the rate of downward motion changes enormously with time for

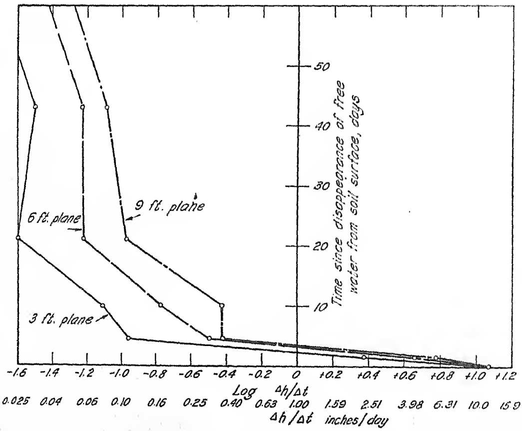

FIG. 8.—The variation with time in flow of water as inches per day across the 3-foot, 6-foot, and 9-foot planes.

TABLE 3.—*Average velocity of water, $\Delta h/\Delta t$, expressed as inches per day moving downward across various soil planes during the time ranges indicated.**

Time range, days		0–3	3–6	6–14	14–28	28–58	58–119	119–217	217–332	332–590	590–842
End date of period	1934						1935			1936	1937
	Oct. 3	Oct. 6	Oct. 9	Oct. 17	Oct. 31	Nov. 30	Jan. 30	May 8	Aug. 31	May 15	Jan. 22
Depth plane, inches				$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$	$\times 10^{-2}$
6	11.6†	0.232	0.0360	0.775	0.00714	0.423	0.0535	0.000	0.509	0.0217	−0.0206
12	11.6†	0.597	0.0107	2.03	0.400	0.785	0.152	0.0316	0.0348	0.0430	−0.0377
18	11.6†	0.978	0.0310	2.89	1.17	1.14	0.261	0.0377	1.18	0.0666	−0.00675
24	11.6†	1.43	0.0603	5.23	1.39	1.98	0.121	0.0438	1.40	0.112	−0.0162
30	11.6†	1.91	0.0937	7.53	1.88	2.58	0.198	0.0694	1.56	0.145	−0.00436
36	11.6†	2.37	0.110	7.95	2.43	3.05	0.0213	0.204	1.95	0.0360	0.0972
42	11.6†	2.76	0.161	8.54	3.16	3.30	0.0770	0.191	2.19	−0.0418	0.136
48	11.6†	3.21	0.225	9.83	3.49	3.79	0.112	0.103	2.37	−0.0279	0.181
54	11.6†	3.64	0.258	11.6	4.44	3.61	0.277	0.0540	2.66	−0.231	0.425
60	11.6†	3.91	0.325	11.2	4.18	4.75	0.0656	0.105	2.89	−0.158	0.437
66	11.6†	4.24	0.295	15.5	5.93	4.68	0.275	−0.114	3.26	−0.238	0.546
72	11.6†	4.51	0.321	16.7	6.00	5.90	−0.0213	−0.0255	3.50	−0.243	0.554
78	11.6†	4.89	0.394	19.6	6.71	6.02	0.495	−0.0418	3.68	−0.257	0.598
84	11.6†	4.99	0.375	21.3	7.69	6.89	0.534	0.0285	3.91	−0.311	0.616
90	11.6†	5.21	0.320	25.2	8.19	7.68	0.479	0.135	4.29	−0.334	0.675
96	11.6†	5.38	0.337	32.0	9.53	7.80	0.744	0.258	4.37	−0.316	0.690
102	11.6†	5.68	0.391	35.0	10.8	7.65	1.04	0.173	4.48	−0.234	0.598
108	11.6†	5.88	0.377	37.4	10.6	8.02	1.01	0.193	4.56	−0.178	0.693

*See footnote to Table 1.
†Final rate of sinking of the water surface just previous to the disappearance of the water from the surface of the soil.

a short period after the water disappears from the surface of the ground, it is impossible to plot it to a linear scale on a graph of reasonable size. In the figure, therefore, the logarithm of the flow across a given plane has been plotted as abscissa and the time has been plotted as ordinate. The actual values for the flow in inches per day are given for convenience below the logarithmic scale.

It should be noticed that one of the curves, namely, that one which represents flow across the 3-foot plane, possesses a different sign of slope between two of the later dates. This simply means that the downward motion has increased during that time. The graph is not extended beyond 60 days owing to the occurrence after this date of negative values among the velocity data of Table 3. The negative values mean that downward movement of water has been replaced by upward movement, a fact which evidently cannot be represented logarithmically.

The average rates of flow across planes at the depths of 3 feet, 6 feet, and 9 feet for dates later than about 60 days are shown by curves C, D, and E, respectively, in Fig. 9, in which $\frac{\Delta h}{\Delta t}$ and time are plotted as ordinate and abscissa, respectively, each to a linear scale. The direction of flow is determined by the position of the velocity value on the graph. Downward movements, i.e., positive velocity values in Table 3, are plotted downwards from, or below, the axis of abscissas; upward movements, i.e., negative velocity values in Table 3, are plotted upwards from, or above, the axis of abscissas. It will be noted that during the later term of the experiment both upward and downward movements occurred, although no upward movement was anticipated at the time the experiment was planned. For this reason long intervals of time elapsed between sampling dates during the latter part of the experiment. Although sampling was insufficiently frequent to allow complete analysis of this undoubted reversal in direction of movement, attention may be directed to certain factors which indicate the probable cause.

No temperature records were kept on the plot. It is common knowledge, however, that the march of soil temperature in relation to depth and time of year exhibits definite trends which are, in part, characteristic of locality. It has been shown (6, 3) that, provided temperature is held constant, the vapor pressure of soil moisture varies only slightly over the range of relative wetness observed in this experiment. It does, however, change markedly with temperature. Bouyoucos (2) found considerable movement of soil moisture due to temperature differences. In searching for the probable cause of the upward water movement in the soil column, temperature records (5) have been consulted which represent soil-temperature measurements made at a point about ½ mile from the experimental plot. It must be emphasized that these temperature records refer to a different member of the same soil series (Yolo loam), a different time (1929–1930), and otherwise somewhat different conditions from those existing in the moisture-movement plot. The magnitudes, of course, may be different, but it is reasonable to suppose that the march of values

would be of the same order. Further, it has been assumed that the annual march of soil temperature would be repeated; an assumption made necessary by the somewhat shorter duration of Smith's published temperature records than that of the moisture-movement experiment.

Attention is here directed to the fact that vapor tends to move from positions of higher to those of lower vapor pressure; whereas liquid, at constant soil-moisture content, tends to flow from points of lower surface tension to those of higher surface tension.

Vapor-pressure and surface-tension values for pure water were obtained corresponding to the soil-temperature values at 4 and 10 feet, respectively. It was assumed, for this purpose, that there existed a negligible salt effect and also a negligible vapor-pressure depression for soil moisture at the high soil-moisture contents concerned. The difference in the water-vapor pressure, Δp, measured in millimeters of mercury at these two positions in the soil column, divided by the vertical distance, Δy, between them in centimeters may then be termed the average vapor-pressure gradient, $\frac{\Delta p}{\Delta y}$, between the two points. Similarly, $\frac{\Delta \sigma}{\Delta y}$ may be termed the average surface-tension gradient between the same two points.

An increase in soil temperature with distance below the soil surface produces for a given soil-moisture content an accompanying increase in vapor pressure, that is to say, a negative vapor-pressure gradient. According to the usual custom, we have regarded the upward direction of "y" as positive. Using the above convention, the force tending to move the vapor is proportional to the negative vapor-pressure gradient. Since we are interested in this force, the average negative vapor-pressure gradient has been plotted as curve A in Fig. 9.

For a given moisture content, an increasing soil temperature with increasing depth has, however, an opposite effect upon the surface tension of soil water in that the surface tension decreases with depth. The force tending to move liquid water is proportional to the gradient of the surface tension using the above convention with respect to sign of "y". The average gradient in surface tension has been plotted as curve B in Fig. 9.

It is possible in Fig. 9, therefore, to make a comparison of all of these functions, $\frac{\Delta p}{\Delta y}$, $\frac{\Delta \sigma}{\Delta y}$, and $\frac{\Delta h}{\Delta t}$, in relation to time since the beginning of the experiment and also in relation to season of the year. Examination of the graph reveals that all of the curves representing the time relations are approximately in phase with one another.

It thus appears evident that temperature conditions at Davis during the winter are such as tend to cause water to move upwards both in the vapor and in the liquid phases. Temperature conditions at Davis in the summer, on the other hand, tend to cause downward movement of soil water in both liquid and vapor phases. The calculated average gradients of both vapor pressure and surface tension

are, accordingly, shown to be in harmony with the results observed in the latter part of the experiment. These results suggest that the observed movements during that time were largely due to temperature changes in the soil.

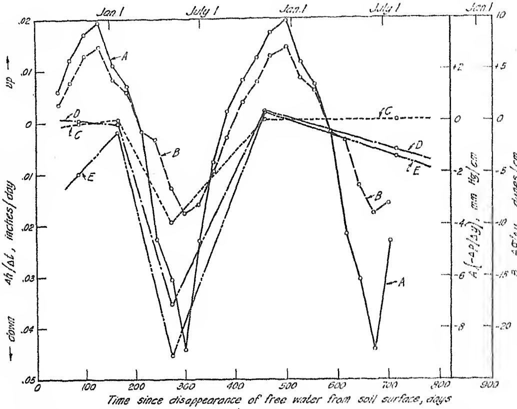

FIG. 9.—Effect of temperature gradients on vertical movements of soil moisture. For convenience the values of $\frac{\Delta p}{\Delta y}$ have been multiplied by 100 and those of $\frac{\Delta \sigma}{\Delta y}$ by 1000.

It is significant in this connection that the comparatively steep slopes in the curves of Figs. 6 and 7 during the period from about 210 to 330 days represent conditions which extended over the summer season and included the months of May, June, July, and August.

SUMMARY

A study has been made of the vertical movement of water in an undisturbed deep soil of alluvial origin from which losses by evaporation and transpiration have been prevented.

The experiment and analysis of results present certain unique features. As distinct from much earlier work in which the water was added in amounts sufficient to moisten only part of the soil column, the present procedure consisted of adding more than enough water to saturate the entire column of soil down to the water table which lay at least 22 feet below the soil surface. A careful examination of the

change in soil moisture over a period of 28 months was made at various depths in the column of soil, the apparent density of which was carefully measured. These furnished the basic data of the experiment by means of which computations were made of the loss by vertical movement in volume of water during various time intervals.

From the summations of these losses above specified planes the average velocities across the corresponding planes were calculated. The downward flow under the influence of gravity rapidly decreased with time. During certain seasons of the year the downward movement was accentuated, whereas during other seasons of the year there was actually an upward movement. These phenomena are explained as probably being caused by the effects of temperature gradients in the soil column on the surface tension and vapor pressure of the soil moisture.

The relative wetness of the soil, as might be expected, was found to increase at a given time with depth from the soil surface, except those parts of the soil column in which there occurred marked departures from the mean moisture equivalent. There was a general decrease with time in the relative wetness at all depths for the entire 28 months.

Altogether, over 180 average velocities of water flow have been calculated across 18 different planes in the soil column and refer to a large number of separate water contents for the soil concerned. The average velocities range from 5.9 to 0.000044 inches per day. Vertically downward movement from the bottom of the 9-foot soil column took place at the average rate of 0.0069 inch per day during an 8-month period immediately after the 590th day.

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GREEN SEEDS IN IMMATURE SMALL GRAINS AND THEIR RELATION TO GERMINATION[1]

A. T. BARTEL[2]

THE presence in wheat of green seeds that germinate poorly was first observed in 1935 in an experiment started to determine the relationship between the degree of maturity of seeds and their viability. A large number of heads of Baart wheat were tagged at flowering on April 9 and representative samples of the tagged heads were collected at 4-day intervals thereafter until maturity. The heads were dried and stored for several weeks, threshed by hand, and the seeds stored in the seed room for at least 6 months before germination tests were made. The seeds obtained 4 and 8 days after flowering were generally predominantly green in color, the color apparently being located entirely in the aleurone layer. None of the 4-day-old seeds germinated, but some of those collected 8 days after flowering were viable. The germination of the samples collected 24, 28, and 32 days after flowering were 97, 71, and 99%, respectively. These data are pertinent to the present discussion because it was noted that the sample collected 28 days after flowering contained 24% of seeds that were entirely green in color. These either did not germinate or were much delayed in germination. The sample collected 24 days after flowering contained 6% of green seeds, while that collected 32 days after flowering contained all normal white seeds. The weights of 100 kernels from the samples collected 24, 28, and 32 days after flowering were 2.66, 3.19, and 4.05 grams, respectively.

The germination of the green seeds in the sample collected 28 days after flowering showed no improvement during the following 2 years. The 3-year average germination of the above three samples was 89, 62, and 95%, respectively. In all of these and subsequent tests, a seed was considered as having germinated when both the radicle and plumule had reached a length of 2 to 3 mm. During germination the green seeds took up water as rapidly as did the white seeds.

GREEN SEEDS AND GERMINATION PERCENTAGE

Although green-colored seeds have occurred commonly in wheat harvested while some of the heads were immature, no data on the germination of such seeds have been found in the literature. To test further the relationship between green color and low germination, heads of Baart, Onas, Sonora, Jenkin, and Marquis wheat were tagged at flowering in the spring of 1936 and subsequently collected, dried, threshed, and germinated. Heads of untagged Sacramento barley also were collected. The methods were similar to those described above for Baart wheat in 1935.

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the Arizona Agricultural Experiment Station, Tucson, Ariz. Received for publication March 26, 1941.

[2]Assistant Agronomist. The author gratefully acknowledges the help of R. S. Hawkins, Agronomist, Arizona Agricultural Experiment Station, in the various phases of this study.

At least one collection in every variety obtained during the period from 16 to 24 days after flowering contained green seeds. Samples collected more than 24 days after flowering contained no green seeds and germinated 95 to 100%. Germination and weight per 100 seeds for the samples gathered during the 16- to 24-day interval are shown in Table 1.

TABLE 1.—*Percentage of green seeds, germination, and weight of 100 seeds of five varieties of wheat and one variety of barley collected 16, 20, and 24 days after flowering in 1936.*

Variety	Period after flowering*								
	16 days			20 days			24 days		
	Green seeds, %	Germination, %	Weight of 100 seeds, grams	Green seeds, %	Germination, %	Weight of 100 seeds, grams	Green seeds, %	Germination, %	Weight of 100 seeds, grams
				Wheat					
Baart.......	61	54	2.54	66	94	3.38	0	100	4.03
Onas........	32	71	2.04	100	13	2.51	0	100	3.37
Sonora......	92	4	1.42	100	3	1.80	0	100	2.46
Jenkin.......	13	98	1.58	0	100	2.26	0	100	2.63
Marquis.....	0	99	1.38	24	99	2.29	0	99	2.80
				Barley					
Sacramento..	0	94	2.24	0	99	2.73	56	47	3.16

*Days after awn emergence in barley.

It will be noted that all 16-day collections, except those of Marquis wheat and Sacramento barley, and all 20-day collections, except Jenkin wheat and Sacramento barley, contained green seed. The collections of Baart, Onas, and Sonora 16 days after flowering were made on April 29; those of the same varieties 20 days after flowering and of Sacramento barley 24 days after awn emergence were made on May 3. In every case the percentage of green seeds for the May 3 collection was greater than for earlier or later dates, suggesting that the percentage of green seeds was related to the calendar date of collection, as well as to the period after flowering. As suggested later, this may have been due to exposure of the samples to sunlight during drying. The collections of Jenkin made 16 days after flowering and of Marquis made 20 days after flowering were made on May 15.

It will be noted, also, that with few exceptions the percentage of green seeds corresponded closely with the percentage that failed to germinate. However, green seeds in Jenkin collected 16 days after flowering and in Baart and Marquis collected 20 days after flowering, germinated about as well as the white seeds.

Data on the comparative rates of germination of white and green seeds from the variety Onas are shown in Table 2. The white seeds were collected 24 days after flowering and weighed 3.37 grams per 100 seeds. The green seeds were collected 20 days after flowering and

weighed 2.51 grams per 100 seeds. At the end of 3 days the white seeds had germinated 100%. Only 4% of the green seeds had then germinated and only 13% had germinated at the end of 5 days.

TABLE 2.—*Rate of germination of green and white seeds of Onas wheat collected 20 and 24 days, respectively, after flowering.*

Material	Percentage germination after hours indicated				
	40	48	72	96	120
Green seeds	0	1	4	11	13
White (normal) seeds	11	99	100	—	—

Heads of Baart, Onas, Sonora, Jenkin, and Ceres wheat and of Vaughn barley and California Red oats also were collected in the spring of 1937. Green seeds were found in only one collection, *viz.*, that of Jenkin obtained 16 days after flowering. This collection contained 22% green seeds and germinated 72%. All others obtained 16 days or more after flowering had normal colored seeds which germinated from 95 to 100%.

EFFECT OF LIGHT EXPOSURE ON THE PERCENTAGE OF GREEN SEEDS

One of the writer's associates suggested that the occurrence of green seeds might have been due to light exposure during drying. Accordingly, representative heads of Baart and Onas wheat were collected on alternate days from 16 to 28 days after flowering in 1939. Half of the heads from each collection were dried in direct sunlight and the remainder dried in the shade. In this material some seeds were found that were partly white and partly green. They are described as intermediate. The weights per 100 kernels and the percentages of white, intermediate, and green seeds in each sample are shown in Table 3.

It will be noted that, in general, there was a much higher percentage of intermediate and green seeds in samples that had been dried in direct sunlight than in those dried in the shade. The only important exceptions were the collection of Baart made 18 days after flowering in which only 13% of the shade-dried seeds were white and the 16-day collection of Onas in which 81% of the shade-dried seeds were white. Since large percentages of green seed were obtained for the early collections dried in sunlight, it would appear that exposure to sunlight during the drying period has a predominating effect.

A few germination tests were made of Baart and Onas heads dried in the shade and in direct sunlight. The average germinations of the white, intermediate, and green seeds were 97, 88, and 41%, respectively.

In the spring of 1940, a number of plants of several varieties were pulled so that some soil adhered to the roots. Part of the plants were dried in direct sunlight and the remainder in the shade. At the same time heads were cut from standing plants of the same varieties, half

TABLE 3.—*Color and weight of seeds from cut heads of Baart and Onas wheat dried in direct sunlight and in the shade in 1939.*

Days after flowering	Weight 100 seeds, grams	Heads dried in					
		Sunlight			Shade		
		White, %	Intermediate, %	Green, %	White, %	Intermediate, %	Green, %
				Baart			
16	2.03	10	52	38	98	2	0
18	2.51	20	43	37	13	45	42
20	3.04	0	11	89	98	2	0
22	3.54	0	75	25	100	0	0
24	3.91	11	81	8	100	0	0
26	4.43	32	68	0	100	0	0
28	4.36	100	0	0	97	3	0
				Onas			
16	2.00	0	22	78	81	17	2
18	2.20	0	31	69	100	0	0
20	2.58	0	17	83	98	2	0
22	3.12	*	*	*	100	0	0
24	3.22	9	91	0	99	1	0
26	3.27	11	70	19	100	0	0
28	—	—	—	—	—	—	—

*Seed eaten by birds.

of which were dried in direct sunlight and the remainder in the shade. All collections were made during the period from 16 days after 1/10 heading to 10 days before maturity. The seeds were green in color at the time the collections were made. The color of the kernels in these samples after drying is shown in Table 4.

TABLE 4.—*Color of seeds from pulled plants and cut heads dried in the shade and in sunlight in 1940.*

Treatment	Kernel color		
	White, %	Intermediate, %	Green, %
Plants pulled:			
Dried in direct sunlight	99	1	0
Dried in the shade	99	1	0
Heads cut from standing plants:			
Dried in direct sunlight	2	51	47
Dried in the shade	76	21	3

It will be observed that the seeds of the pulled plants were practically all white regardless of whether they had been dried in the shade or in direct sunlight. However, when comparable heads cut from

standing plants were dried in a similar manner, 2% of the seeds were white when dried in the sunlight and 76% when dried in the shade.

EFFECT OF TREATMENTS ON GERMINATION OF GREEN SEEDS

No increases in the percentage of germination of the green wheat seeds have been obtained with (1) treating the seed during germination with 0.5 and 1.0% thiourea; (2) germinating the seeds at high and low temperatures; (3) exposing the embryos to different amounts of electric light at various stages in germination; and (4) treating the seeds at several stages of germination with water extract from lightly mashed white seeds at several stages of germination.

EFFECT OF SEED COLOR ON SEEDLING GROWTH

The seedling growth of plants produced by white, intermediate, and green seeds was determined in 1940. The white seeds were obtained from rod rows of Jenkin wheat cut by hand and dried in the shade, and the intermediate and green seeds were obtained from a similar adjacent row cut the same day but dried in the sunshine. The wheat was hand-threshed and the three lots of seed were sorted to a comparable size of 1.78 grams per 100 seeds. The seeds were planted in boxes containing sand and samples of 15 to 25 seedlings were harvested on alternate days during the period between 7 and 25 days after planting. The average germination of the white, intermediate, and green seeds was 98, 86, and 47%, respectively. The plant weights of the seedlings are shown in Fig. 1.

It will be noted that the weight per plant from the green seeds which germinated did not exceed about half that from the white seeds until about 19 days after seeding. The rather sharp rise in the curve for the plants produced by green seeds after 17 days may have been due partly to the lower germination and fewer plants and greater space per plant, as compared with those from the intermediate and white seeds. The plant weights produced by the intermediate seeds were generally slightly lower than those produced by the white seeds. The average dry weight per plant produced by the green seeds for all collections was 58% and for the intermediate seeds 89% of that produced by the white seeds.

DISCUSSION

It would appear to have been clearly shown that drying heads in direct sunlight has a predominant effect on the percentage of green seed. This is not the complete story, however, as shown by the differences in percentage of green seeds of Baart and Onas wheat (Table 3) when dried in direct sunlight. These differences may have been due to (1) differences in the intensity of the sunlight during drying or (2) to the stage of development of the wheat grain. The appearance of 42% of green seeds in Baart collected 18 days after flowering and dried in the shade suggests that there is a stage of development during which green seeds are most likely to occur. However, the fact that this was the only collection in either Baart or Onas dried in the

shade that had over 2% green seeds also indicates a possible error in labeling the samples. The appearance of large percentages of green seeds in the samples of Baart, Onas, and Sonora collected 16 and 20

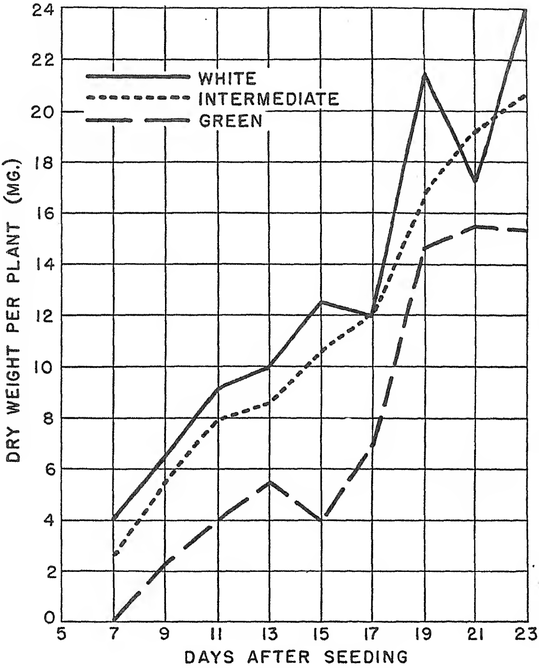

FIG. 1.—Seedling growth of plants produced from white, intermediate, and green seeds, 1940.

days after flowering (Table 1) may have been due to the stage of development or to the drying of the heads in sunlight, while the few collections of the same varieties made later may have been dried in the shade. At the time these collections were made the relation of green seeds to exposure to sunlight was not realized and the exact way in which they were dried is not known.

It has been suggested that the appearance of a high percentage of green seeds when the heads were dried in direct sunlight and a low percentage when dried in the shade may have been due to the higher rate of drying in the former case rather than the effect of sunlight as such. No data bearing on this point have been collected.

The data in Table 4 show that, even though the grains were green when collected, the threshed seeds of plants pulled with soil adhering to the roots were predominantly white regardless of whether they had been dried in the shade or in the sunlight. This is important in relation to hybrid plants pulled prior to maturity, the threshed seed of which is later to be used for propagation or for genetic studies.

It also has been clearly shown that green seeds tend to germinate decidedly less than normal white seed. Since none of the germination tests was made until at least 6 months after the samples were collected, any "after ripening" dormancy was largely eliminated.

SUMMARY

Green seeds have been found in wheat and barley heads collected during the interval from approximately 12 to 24 days after flowering. Such samples stored for at least 6 months before germination tests were made have in general germinated poorly and have produced relatively weak, slow-growing seedlings.

The occurrence of green seeds appears to be due largely to the way the collections are made and their exposure to sunlight during drying. Plants pulled with soil adhering to the roots produced mostly white seeds regardless of exposure during drying, whereas heads cut from comparable plants at the same time produced 47% green seed when dried in direct sunlight and 3% when dried in the shade.

It would appear that the method of collecting and drying plants before maturity merits consideration, especially if the seeds are to be used for propagation or for genetic studies.

THE RELATION OF TANNIN CONTENT OF SERICEA LESPEDEZA TO SEASON[1]

R. E. STITT AND I. D. CLARKE[2]

AS a forage crop for hay and pasture on land of low fertility in the southeastern part of the United States, few plants can compete in yield and drought resistance with sericea lespedeza, *Lespedeza cuneata* (Dum. de Cours) G. Don.[3] It is probable, however, that the extended use of this plant has been retarded to some extent by conflicting reports regarding its palatability and feeding value. The literature dealing with these points has been adequately reviewed by Clarke, Frey, and Hyland[4] and by Pieters,[5] and need not be further discussed here.

Clarke, Frey, and Hyland[6] suggested that tannin may be the cause for the apparent dislike some animals have for sericea and reported on the tannin content of samples of hay harvested at weekly intervals from May 29 to July 31. This is the period during which sericea would be cut for hay. They found a progressive increase in tannin up until the end of July, but had no data to show whether or not there was any change in the fall.

The tannin content of sericea during the latter half of the growing season would be of particular interest to those who use it for grazing. This is especially true since much of the controversy regarding palatability of sericea is based on observations of grazing animals.[7]

In the present report analyses are given of plants harvested throughout the growing season.

EXPERIMENTAL PROCEDURE

During the season of 1936, samples of sericea (*Lespedeza cuneata*, F.C. No. 17291) were harvested at Statesville, N. C., at 14-day intervals from May 5 to October 20. The material for analysis was all first-cutting hay obtained from square-yard areas on random-selected duplicate plots in a field seeded in 1931.

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[1]Cooperative investigations of the Hides, Tanning Materials, and Leather Division, Eastern Regional Research Laboratory, Bureau of Agricultural Chemistry and Engineering and the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture; and the North Carolina Department of Agriculture and the North Carolina Agricultural Experiment Station, Raleigh, N. C. Received for publication March 26, 1941.

[2]Assistant Agronomist and Chemist, respectively.

[3]This perennial lespedeza has been called *Lespedeza sericea* Benth. up to the present time by the U. S. Dept. of Agriculture. According to the international nomenclature, however, it is *Lespedeza cuneata* (Dum. de Cours) G. Don and the name *Lespedeza sericea*, therefore, has been dropped as a scientific name for this plant. However, sericea, or sericea lespedeza, is used herein as a common name because it is already established and doubtless will continue to be used by farmers and others interested in the plant.

[4]CLARKE, I. D., FREY, R. W., and HYLAND, H. L. Seasonal variation in tannin content of *Lespedeza sericea*. Jour. Agr. Res., 58:131–139. 1939.

[5]PIETERS, A. J. Lespedeza sericea and other perennial lespedezas for forage and soil conservation. U. S. D. A. Circ. 534. 1939.

[6]*Loc. cit.*

[7]See footnote 5.

The green plant material was cured in paper bags in a well-ventilated, dark room. Moisture in the fresh material was determined by oven drying a portion at 100° C. After the samples were air-dry, the separation into leaves and stems was made.

The tannin content was determined by the hide-powder method of the American Leather Chemists' Association.[8] This method gives what was designated by Clarke, Frey, and Hyland[9] as total tannin. Fixable tannin was not determined. No tests other than the above-mentioned determination were made with the object of isolating and identifying the true tannin. The results, therefore, actually show matter absorbed by chromed hide powder under certain arbitrarily defined conditions. In preparing the extract solution for analysis, 25 grams of air-dry leaf and 50 grams of stem material were extracted separately by the reflux method of the American Leather Chemists' Association and each extract was made up to 1 liter. For removing tannin, 45 grams of wet, chromed hide powder were used per 200 ml of leaf extract and 15 grams for the same volume of stem extract.

The tannin concentrations in the leaf extracts varied from 2 to 4 grams of tannin per liter, the lower concentrations being for samples taken early and late in the season. The method specifies that the tannin concentration shall be not less than 3.75 nor more than 4.25 grams per liter. Lower concentrations may give high tannin values. However, results in which varying amounts of material were extracted or different amounts of hide powder were used indicate that they are not high by more than 0.2 or 0.3%.

RESULTS

Leafiness decreased with the aging of the plant from 75.7% in the first samples to 44.9% in the samples at the end of the season, as shown by Table 1. The plants started to bloom in late August and blossoms and seed were included in the leaf samples, which may partly account for the fluctuation in leafiness during August and

TABLE 1.—*Percentage of leaves and stems in sericea lespedeza cut at 14-day intervals in 1936 at Statesville, N. C.*

Date harvested	Moisture-free basis	
	Leaves, %	Stems, %
May 5	75.7	24.3
May 19	68.2	31.8
June 2	67.3	32.7
June 16	69.4	30.6
June 30	68.3	31.7
July 14	64.1	35.9
July 28	56.8	43.2
Aug. 11	56.2	43.8
Aug. 25	57.8	42.2
Sept. 8	50.2	49.8
Sept. 22	53.7	46.3
Oct. 6	51.2	48.8
Oct. 20	44.9	55.1

[8]American Leather Chemists' Association. By-laws and methods of sampling and analysis. 1930.

[9]*Loc. cit.*

September. The stems reach their ultimate size by the time of first bloom so that the decrease in leafiness after the middle of August is due to dropping of leaves.

Data on the soluble solids and tannin contents are given in Table 2. Values for the whole plant were calculated from data for the leaf and stem portions. The soluble-solids content of the leaves increased from about 30% during the first part of May to 37% in July, then decreased to 27.7% at the end of the season. The content of soluble solids in the stems decreased throughout the season from about 23% to 14%. In the whole plant there was little change in soluble-solids content until the first of July after which there was a decrease from about 31% to 20%.

TABLE 2.—*Tannin content on moisture-free basis of sericea hays harvested at Statesville, N. C., in 1936.*

Date of harvest	Leaves*		Stems*		Whole plant†	
	Soluble solids, %	Soluble tannin, %	Soluble solids, %	Soluble tannin, %	Soluble solids, %	Soluble tannin, %
May 5	29.9	8.3	—	—	—	—
May 19	32.3	11.6	22.9	2.0	29.3	8.5
June 2	34.8	13.4	20.5	2.8	30.1	9.9
June 16	35.9	15.3	20.1	2.9	31.1	11.5
June 30	37.2	18.0	17.9	2.7	31.0	13.1
July 14	35.1	16.2	16.4	2.1	28.4	11.1
July 28	37.5	16.9	15.8	2.0	28.1	10.5
Aug. 11	32.6	13.9	15.4	2.0	25.0	8.7
Aug. 25	32.8	13.6	14.2	2.2	24.9	8.8
Sept. 8	30.2	12.0	15.1	2.0	22.7	7.0
Sept. 22	31.8	13.0	14.3	2.4	23.7	8.0
Oct. 6	27.6	7.8	13.9	1.8	20.9	4.9
Oct. 20	27.7	8.8	13.9	2.0	20.1	5.1

*Non-tannin values are not given but can be obtained by subtracting the figures for tannin from those for soluble solids.
†Calculated from values for the leaf and stem portions.

The tannin content of the leaves more than doubled between the first of May and the end of June, the increase being from 8.3% to 18.0%. After the first of July there was a decrease in tannin content and the last sample taken in the fall contained about the same amount of tannin as the first sample taken in the spring.

In October the leaf tannin was much lower than in September, the values being only 7.8 and 8.8% for the two October samples as compared with 12 and 13% for those taken in the preceding month. Part of this decrease in tannin was probably caused by seed for there was a considerable amount of mature seed in the October leaf samples. Aqueous extracts of ground seed and leaves will form a precipitate when mixed, possibly because of a combination of seed protein and leaf tannin. The proportion of seed in the October samples was not determined, but data on yields of hay and seed indicate that good stands of sericea should contain 10 to 15% of seed at seed harvesting time, which is in October. To obtain some quantitative data on the

effect of seed, a leaf sample containing 13.5% of tannin was mixed with enough ground sericea seed to form 12.5% by weight of the mixture. Analysis then showed only 10.1% of tannin in the mixture. If the seed had acted simply as inert matter 11.8% of tannin should have been found. The seed, therefore, caused a "loss" of 1.7% of tannin. Probably the October samples would have shown 10 or 11% of tannin if the seed had not been present; that is, there would have been only a moderate decrease in October instead of a relatively large one.

DISCUSSION

The increase in tannin content of sericea during the first part of the season is similar to that found by Clarke, Frey, and Hyland[10] for their samples taken in Virginia in 1935. They found, however, a continual increase in tannin content up to July 31 instead of a maximum at the end of June, although the change during July was very small. Their last sample might well have been taken when the tannin content was highest for the season.

A maximum tannin content near the middle of the growing season has been observed for other series of samples taken in other years and seems to be a general rule. The difference in time at which the maximum tannin content was reached for the samples reported on here and those of Clarke, Frey, and Hyland may have been caused either by a difference in weather conditions during the two years or by a difference in actual age of leaves and stems, since growth starts earlier in the spring in North Carolina than in Virginia.

SUMMARY

Samples of sericea lespedeza were taken at 14-day intervals from May 5 to October 20, 1936, from a field at Statesville, N. C., seeded in 1931.

Leafiness decreased throughout the season.

Tannin in the leaves increased until June 30, then gradually decreased until September 22. The October leaf samples were appreciably lower in tannin than the September ones partly because of mature seed in the former. The first and last leaf samples collected contained less than half as much tannin as the midseason ones.

All stem samples were low in tannin.

[10] *Loc. cit.*

MINERAL NUTRIENT EXTRACTION AND DISTRIBUTION IN THE PEANUT PLANT[1]

LELAND BURKHART AND N. R. PAGE[2]

INVESTIGATORS have recently used the fresh plant tissue as an index of mineral nutrient deficiencies and excesses in the growing plant and have found a high correlation between the concentration of inorganic constituents in the conducting tissues and fertilizer treatment and yield (2, 3, 4, 5, 8, 11, 12).[3] The analysis of fresh tissue has also been found useful in studying the effect of one nutrient on the rate of absorption of another and should be useful in determining the range in the concentration of a specific nutrient in relation to its deficiency or toxicity to a particular plant.

The purpose of the present investigation has been to study the concentration of mineral nutrients in the fresh tissues of the peanut plant as an index of soil fertility and fertilizer requirements of the peanut. Under field conditions unbalanced relationships exist in plants with respect to the soluble mineral nutrient content. Deficiencies or excesses of one or more of the mineral constituents can be readily determined by proper selection of plant tissue and standardization of methods of analysis and the unbalanced conditions existing in young plants can be corrected by the proper fertilizer supplements. Methods of extraction and analysis of plant tissue, distribution of mineral elements within the peanut plant, and the effect of fertilizer supplements on unbalanced conditions within the peanut with respect to yield are presented in this paper.

MATERIALS AND METHODS

The results presented in this paper were obtained from nine fertilizer field experiments located in the Coastal Plain region of North Carolina. These experiments were conducted on the following soil types: Norfolk, sandy loam, Ruston sandy loam, Dunbar-Lenoir sandy loam, Coxville sandy loam, Wickham sandy loam, and Portsmouth sandy loam. The soil tests showed a wide range in mineral nutrient concentration.

Plant samples were taken at three stages of growth, *viz.*, the vegetative stage, early fruiting stage, and maturity. Plants were taken at random from each treatment, six to eight plants being considered a representative sample. The plants were pulled up by the roots, placed in a paper bag, and rushed to the laboratory for analysis. Precautions were taken to prevent loss of moisture and the samples were analyzed immediately. The plants were divided into nine portions, *viz.*, top, middle, and lower blades; top, middle, and lower petioles; and top, middle, and lower stems.

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[2]Assistant Agronomist and Research Fellow in Agronomy, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 755.

EXTRACTION

A number of methods for the extraction of mineral nutrients from plants have been proposed and developed. Gilbert and Hardin (6), Pettinger (10), and McCool and Weldon (8) used the expressed sap; Lowry and Taber (7) and Pierre and Pohlman (11) used the exuded plant sap; Emmert (4) and Carolus (2) used a weak acetic acid extract; and Gardner and Robertson (5) used a cold water extract. Correlations were found between the concentration of mineral nutrients in fresh plant tissue and available nutrients in the soil. If treatment of beet petioles with cold water for 12 to 24 hours removes soluble phosphate (5), it seems reasonable that boiling water should accomplish the same purpose in a much shorter period of time as hot water destroys the cells, thus rendering them permeable to mineral nutrients.

In the method used, 20 grams of plant material were minced with a sharp knife. After thoroughly mixing the minced tissue, duplicate 5-gram samples were placed in 250-ml beakers and about 200 ml of distilled water added and boiled for 2 hours, the volume of water being kept nearly constant. This volume of water is large enough to exert a churning action on the plant material, thus facilitating extraction. At the end of 2 hours, the solution was decanted, the plant material washed several times with small amounts of distilled water, and the extract and washings made up to a volume of 250 ml. One ml of glacial acetic acid was added to 100 ml of the extract to aid in clarification and to prevent the carbon black from adsorbing any of the mineral nutrients. Then from 0.5 to 1 gram of decolorizing charcoal was added, depending on the color of the extract. The mixture was shaken two or three times by hand, allowed to stand for 10 minutes, and then filtered through ordinary filter paper. Fifty ml of the clear extract is sufficient to run tests for calcium, magnesium, potassium, phosphates, sulfates, and nitrates.

Tests were run to determine the completeness of the extraction at the end of the 2-hour boiling period and to determine the rate of extraction of each individual mineral nutrient. Samples prepared as already described were boiled for 30 minutes and analysed for mineral nutrient concentration. Five successive extractions were made in a similar manner and analyzed separately

The concentrations of mineral nutrients extracted in successive half-hour boilings are shown in Fig. 1. In all cases the greatest amount of nutrients is extracted during the first thirty minutes of boiling. At the end of ninety minutes, most of the nutrients have been extracted. Very small additional amounts of minerals are being removed after 120 minutes of boiling. In general, it takes longer to extract calcium than any of the other mineral nutrients, while most of the potassium is removed at the end of 30 minutes. The accumulated removal of nutrients by four successive 30-minute extractions was found to be equivalent to continuous extraction for 2 hours.

ANALYSIS OF EXTRACT

The dilutions of cleared extract used below were found most applicable to the peanut; however, experiments with cotton, soybeans, and blueberries have shown that other dilutions may be necessary for different species.

Calcium (CaO).—To 5 ml of the filtrate in a test tube add 1 ml of a saturated solution of ammonium oxalate, shake immediately, and compare the turbidity developed with a set of standards, treated similarly, against a background of black lines. Multiply the observed concentration of calcium oxide by 50 to obtain

the concentration as parts per million in the plant tissue. It has been found that the results check with duplicate samples and is better correlated with fertilizer treatments if the solution is shaken immediately upon the addition of the ammonium oxalate instead of waiting a few minutes.

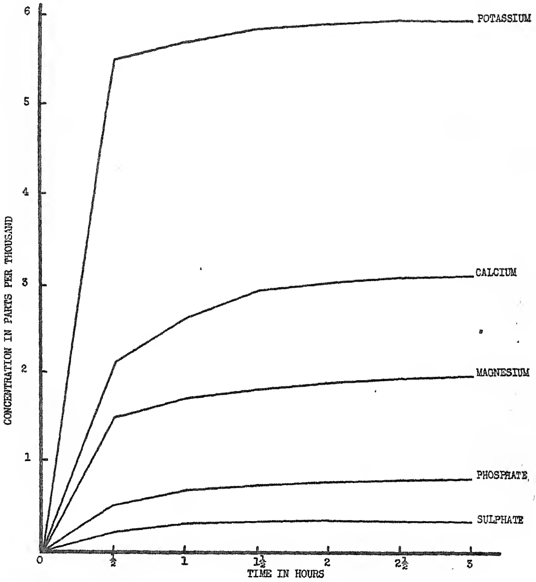

FIG. 1.—The time factor in the complete extraction of the respective soluble mineral nutrients from peanut leaf tissue by means of boiling water.

Potassium ($K2O$).—In making the potassium, magnesium, and phosphate tests, dilute 5 ml of the filtrate to 25 ml. Place 5 ml of diluted (1:5) extract in a small test tube, cool in an ice bath or refrigerator to 10° C (1), add 60 mg of dry sodium cobaltinitrite, and shake into solution; then add 5 ml of 95% ethyl alcohol and shake. Compare the turbidity developed with a set of prepared standards. Diffused artificial light and a background of black lines as used by Carolus (2) have been found to be the best method of comparing turbidities. Multiply the observed concentration by 250 to obtain the concentration in parts per million in the plant tissue.

Experiments on the effect of temperature, pH, and method of adding the precipitating agent have shown that a temperature of 10° C, a pH of 6, and dry sodium cobaltinitrite give the best results (1).

The objection to the use of the dry form of sodium cobaltinitrite is the difficulty experienced in obtaining the same amount each time. A hollow glass tube, calibrated along the tube to deliver 60 mg, and a glass rod make a simple, fast, and accurate instrument for adding the sodium cobaltinitrite. A single filling is sufficient for 8 or 10 tests.

Magnesium (*MgO*).—Place 1 ml of diluted (1:5) extract in a spot plate, add 2 drops of a 10% NaOH solution, stir, then add 1 drop of a 0.15% Titan Yellow solution and again stir well. Compare the intensity of the pink color developed to a set of similarly treated standards. Multiply the determined reading of MgO by 250 to obtain the concentration in parts per million in the plant tissue. It is easier to distinguish differences in color intensity against the white background of a spot plate than in a test tube. It is important to add the same amount of Titan Yellow to each test as different concentrations of the dye give different intensities in color. Also, it is necessary to keep the concentration of MgO below 30 p.p.m. if accurate readings are to be made, as the precipitate coagulates and separates out rapidly in higher concentrations.

Phosphates (P_2O_5).—Place 1 ml of diluted (1:5) extract in a spot plate, add 2 drops of ammonium molybdate solution, made according to A.O.A.C. methods (9) and diluted 1:4, stir, then add 1 drop of a 0.25% solution of 1-amino-2-naphthol-4-sulfonic acid in 15% $NaHSO_3$ as recommended by Emmert (3), and stir. Allow the solution to stand for 2 minutes to obtain maximum color and then compare the intensity of the blue color developed with a set of similarly treated standards. Multiply the observed concentration by 250 to obtain the concentration of phosphate in parts per million in the plant tissue. Differences in the intensity of the blue color are also more readily evaluated against the white background of a spot plate than in a test tube.

Sulfates (SO_4).—To 5 ml of the filtrate in a test tube add 1 drop of concentrated hydrochloric acid and 2 drops of a 10% barium chloride solution, shake, and compare the turbidity developed with a set of prepared standards against a background of black lines. Multiply the observed concentration by 50 to obtain the concentration in parts per million in the plant tissue.

RESULTS

DISTRIBUTION OF MINERAL NUTRIENTS

Many investigators have recommended different portions of the plant as the most desirable to test for mineral nutrient deficiencies. Emmert (4), Carolus (2), and Gardner and Robertson (5) recommend the mature petioles and stems. Thornton (12) states that, in general, phosphate should be determined on the actively growing portions of the plant. He also recommends the base of the leaf for the determination of potassium in cereals and grasses.

As no work of this kind has been done on peanuts, it seemed advisible to make tests on different parts of the plant to determine what tissues were most suitable for each mineral nutrient.

The average concentrations of nutrients in different tissues of the peanut plant are shown in Fig. 2 and the range in concentration for each portion is shown in Table 1. The average concentration of the

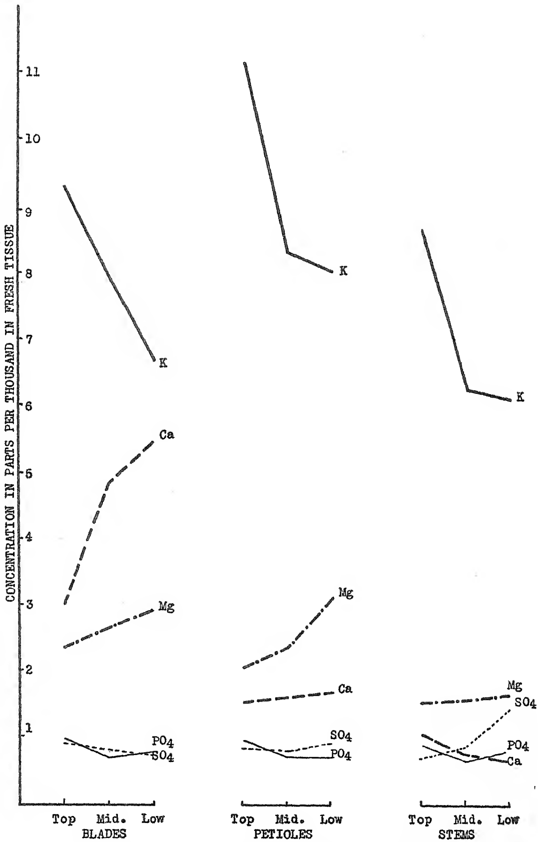

FIG. 2.—Average concentrations of soluble mineral nutrients in the respective parts of the peanut plant sampled near the middle of the growing season (early fruiting stage).

respective mineral constituents, and especially the range in concentrations of the respective minerals, should be taken into consideration in deciding on the most suitable portion of the plant to test for each element.

The data in Table 1 and Fig. 2 show the portions of the peanut plant most desirable to select for evaluating the levels of the respective mineral nutrients.

TABLE 1.—*Range in nutrient content of various portions of the peanut plant.**

Portion of plant	CaO, p.p.m. †	K_2O, p.p.m.†	MgO, p.p.m.†	P_2O_5 p.p.m.	SO_4 p.p.m.
Top blades....	500–7,500	1,620–21,870	500–5,620	150–4,370	20–3,750
Middle blades.	1,120–12,000	1,250–18,750	620–6,500	70–1,870	50–3,000
Lower blades..	2,250–12,370	1,120–17,250	570–7,750	70–1,500	50–3,250
Top petioles...	250–4,500	1,000–36,250	250–5,500	100–2,700	20–5,500
Middle petioles	100–6,000	500–22,000	250–6,250	100–3,750	20–4,500
Lower petioles	50–6,250	250–21,250	250–8,750	100–2,250	20–5,250
Top stems....	50–3,270	620–18,750	120–5,250	100–3,750	60–2,250
Middle stems.	20–2,120	620–18,750	250–3,750	20–3,120	20–2,870
Lower stems..	20–2,250	250–15,620	120–5,620	20–1,870	10–5,620

*Results obtained from all tests run on nine fertilizer field experiments and expressed in p.p.m. of the fresh plant tissue. Sampled near the middle of the growing season or early fruiting stages.
†Soluble calcium, potassium, and magnesium expressed as oxides.

The wide range in calcium concentrations in the middle and lower blades indicates that the calcium levels can satisfactorily be determined in these tissues.

Potassium, in general, is highest in young portions of the plant, the top petioles having the highest average concentration of potassium and the widest range.

Magnesium is higher in the older mature tissues. The bottom petioles have the highest average concentration of magnesium and the widest range; however, the lower blades could also be used to indicate magnesium deficencies.

There is very little difference in the average concentration of phosphates in different portions of the peanut plant, although the concentration in young tissue is consistently higher than that in older tissues.

Sulfates tend to accumulate in the lower portions of the plant, especially in the lower petioles and stems.

The mineral nutrient relationships in the blades of the peanut plants at three stages of growth are shown in Table 2 and Fig. 3.

The first sampling was taken during the vegetative stage 2 months after planting. This stage is most practical from the standpoint of foliar diagnosis in relation to fertilizer supplements as side dressings. Gypsum is often applied on the foliage at this stage. The second sampling was taken during the early fruiting stage, 3 months after planting or 1 month after gypsum is usually applied. The third sampling was taken at maturity when the plants were harvested 5 months after planting. As peanut plants defoliate considerably upon approaching maturity, only the upper 20% of the blades remained on the plants

TABLE 2.—*Range in concentrations of mineral nutrients in blades of peanut plants sampled at three stages of growth.**

Sampling†	Portion of plant	CaO, p.p.m.	K_2O, p.p.m.	MgO, p.p.m.	P_2O_5, p.p.m.	SO_4, p.p.m.
			Minimum and maximum concentrations			
1st	Top blades	1,250–4,750	1,620–21,870	500–5,500	150–2,400	20–1,500
	Middle blades	1,620–6,250	1,620–17,500	620–6,500	70–1,750	50–1,370
	Lower blades	2,250–10,500	1,120–15,000	1,250–7,750	70–1,500	50–1,370
2nd	Top blades	500–7,500	3,000–20,000	870–5,620	350–4,370	120–3,750
	Middle blades	1,125–12,000	1,250–18,750	1,250–6,250	250–1,870	120–3,000
	Lower blades	2,250–12,370	1,250–17,500	570–6,250	370–1,120	50–3,250
3rd	Blades	2,620–17,250	5,620–12,125	1,050–5,000	500–1,870	250–3,500
			Average concentration			
1st	Top blades	2,287	9,931	1,798	948	471
	Middle blades	3,860	8,428	2,528	652	445
	Lower blades	5,090	6,910	2,980	730	370
2nd	Top blades	3,437	8,850	2,662	922	1,177
	Middle blades	5,396	7,655	2,689	703	949
	Lower blades	5,620	6,510	2,840	760	960
3rd	Blades	6,362	10,028	2,693	1,090	1,539

*Results obtained from nine fertilizer field experiments and expressed in p.p.m. of fresh leaf tissue.
†1st sampling during vegetative stage; 2nd sampling during early fruiting stage; 3rd sampling at maturity (harvest).

for final sampling. Although these were top blades positionally, they were physiologically mature.

The average concentration of calcium increases with the maturity of the plant. The average concentration of potassium decreases from the first to the second sampling but increases from the second to the third sampling, probably due to the upward translocation of the mobile potassium from the lower blades as the plants mature. Magnesium, phosphate, and sulfate increase in average concentration from the first to the third sampling.

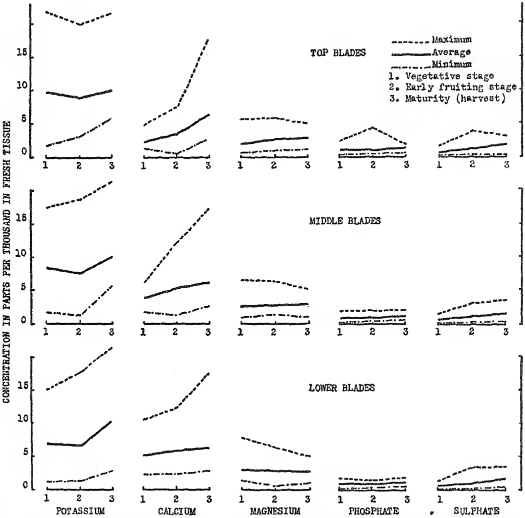

FIG. 3.—Maximum, average, and minimum concentrations of soluble mineral nutrients in the top, middle, and lower blades of the peanut plants sampled at three stages of growth.

The average concentration of potassium is higher and the range wider in the top and middle blades, but deficiencies are more evident in the lower blades, especially at the first sampling. The average concentration of calcium and magnesium is higher and the range wider in the lower blades during the vegetative stage. At the first and second sampling the average concentrations of phosphate and sulfate do not differ markedly in the top, middle, and lower blades.

As time limits the number of tests that can be run, a portion of the plant most nearly suitable for testing for all nutrients had to be selected. After careful consideration, the lower blades were selected for sampling for the following reasons:

1. Peanuts tend to respond more to calcium than to any other mineral nutrient. The lower blades are the most desirable portion of the plant in which to determine the calcium levels. The lower blades are more suitable than the middle and upper blades for determining potassium and magnesium levels.
2. The mineral concentration of mature tissues is probably less affected by variable climatic conditions than young actively growing tissue.
3. Mature lower blades tend to show deficiencies in mineral nutrients before young portions of the plant. Potassium and magnesium are translocated from older tissues to the younger actively growing tissues when deficiencies exist.
4. Preliminary studies have indicated that there is a higher correlation between the nutrient concentration in the lower blades and the response to fertilizer treatment than with other portions of the plant.
5. The lower blades can be used for analysis during the vegetative stage as well as in the early fruiting stage.

NUTRIENT CONCENTRATION AND FERTILIZER RESPONSE

The results presented in Table 3 showing the relations between the concentration of mineral nutrients in the lower blades and fertilizer response were obtained from fertilizer field experiments with the Virginia Bunch variety. These experiments were located in the Coastal Plain region of North Carolina. It is interesting to note that when the concentration of a specific nutrient in a given soil type falls

TABLE 3.—*Concentration of nutrients in the lower blades and fertilizer response.**

Experiment No.	Soil type	CaO, p.p.m.	K_2O, p.p.m.	P_2O_5, p.p.m.	Fertilizer material resulting in increased yield
I	Ruston sandy loam	8,000	1,250	750	Potash
II	Dunbar-Lenoir sandy loam	2,500	8,125	375	Lime, gypsum, superphosphate
III	Ruston sandy loam	3,000	4,375	475	Gypsum, potash, superphosphate
IV	Portsmouth sandy loam	2,250	10,620	750	Lime, gypsum
V	Norfolk very fine sandy loam	3,500	6,250	625	Lime
VI	Coxville very fine sandy loam	7,750	3,750	750	Potash
	Average†	4,500	5,728	621	

*Analysis of no-treatment plots expressed in p.p.m. of fresh tissue sampled near the middle of the growing season or early fruiting stage.
†Average of no-treatment plats on all six field experiments.

much below the average for the six soil types that the addition of this nutrient in the fertilizer produces favorable responses. In every case, when the concentration of either calcium, potassium, or phosphorus in a specific experiment was appreciably below the average, a fertilizer material containing this mineral nutrient gave an increase in yield. Since phosphorus was added as superphosphate and since a response to superphosphate was obtained only in cases where the concentration of calcium was low, the increase in yield might be due to the calcium in the superphosphate.

The results seem to indicate that peanuts of the Virginia Bunch variety will respond to calcium, potassium, and phosphorus if the concentrations of these soluble mineral nutrients in the lower blades sampled during the early part of the growing season are much below 4,500, 5,500, and 600 p.p.m., respectively.

CALCIUM AND POTASSIUM RELATIONSHIPS

Fig. 4 shows some interesting relationships between calcium and potassium in the plant and the plant's response to fertilization. In most cases the potassium-treated plots are lower in calcium than those receiving no-treatment, but only in half of the experiments is the concentration of potassium in the gypsum-treated plots lower than in the no-treatment plots.

In general, the fertilizer supplements for peanuts are limited to two or possibly three mineral nutrients. As the peanut plant is a legume, nitrogen is not normally a limiting nutrient. Phosphorus is added to the soil as superphosphate and it is questionable whether it is the calcium or the phosphorus in the superphosphate that produces a response. It seems that the unbalanced mineral conditions within the peanut plant resulting in poor yields under the conditions of these experiments is due largely to excesses or deficiencies of calcium or potassium. Magnesium may affect these unbalanced conditions through its effect on calcium and potassium absorption.

Four experiments are shown in Fig. 4, representing four sets of conditions that may be encountered, namely, high calcium and high potassium, high calcium and low potassium, low calcium and high potassium, and low calcium and low potassium.

Experiment I, conducted on a Wickham sandy loam, represents a condition of high calcium and high potassium. The addition of either calcium or potassium singly results in a slight decrease in yield below the no-treatment plat.

Experiment II, carried out on a Ruston sandy loam, represents a condition of high calcium and low potassium. The addition of calcium causes a decrease in yield below the no-treatment plot, while an application of potassium produces an increase in yield above the no-treatment. In this experiment, the calcium-potassium relation is unbalanced. The addition of more calcium tends to make the relation more unbalanced and probably causes potassium deficiency. The addition of potassium increases the concentration of potassium in the plant and represses the intake of calcium, thus bringing the conditions more in balance.

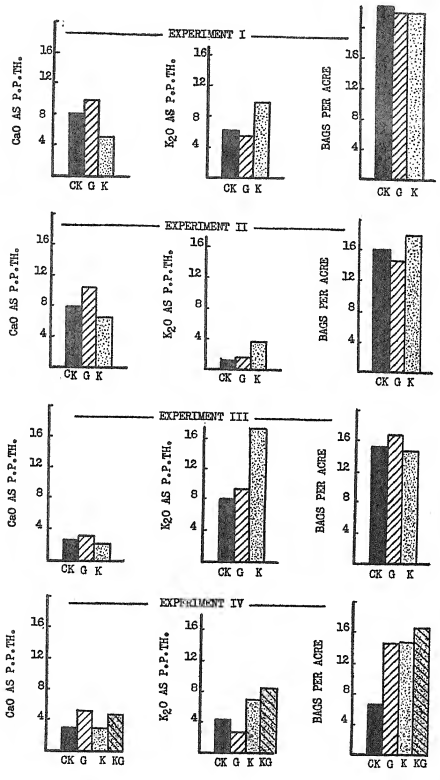

FIG. 4.—Calcium-potassium concentrations in the lower blades of the peanut plant as related to fertilizer supplements and yields in bags of peanuts (88 pounds) shelling 60% good kernels. In each of the respective field experiments Ck = plats which received no fertilizer supplements; K = plats which received potassium supplied as muriate at planting at the rate of 75 pounds per acre; and G = plats which received gypsum applied to foliage at blooming at the rate of 400 pounds per acre.

Experiment III, carried out on a Dunbar-Lenoir fine sandy loam, represents a condition of low calcium and high potassium. The addition of calcium results in increased yield over the no-treatment plot, while an addition of potassium causes a decrease in yield below the no-treatment. The addition of calcium tends to relieve the unbalanced conditions within the plant, while the addition of potassium makes them more pronounced.

Experiment IV, conducted on a Ruston sandy loam, represents a condition of low calcium and low potassium. In this experiment, the concentration of both nutrients is below the optimum and the addition of either nutrient results in an increase in yield over the no-treatment plot. The greatest increase in yield is obtained when both calcium and potassium are added.

Fig. 4 also shows the relation between nutrient concentration and fertilizer treatment. The addition of either calcium or potassium to the soil invariably resulted in an increase of that mineral nutrient within the plant tissues. In these four experiments, the concentration of calcium in the gypsum-treated plots was from 500 to 2,600 p.p.m. higher than the calcium concentration in the no-treatment plots and the potassium concentration was from 2,400 to 9,100 p.p.m. higher in the potassium plots than in those receiving no-treatment.

Information concerning the characterization of the soils employed in these fertility studies and the interpretation of the plant tissue tests with the soil tests and other basic data will appear in a later publication.

SUMMARY AND CONCLUSIONS

1. Extraction of plant tissue with hot water for 2 hours is sufficient to remove from the peanut plant the soluble mineral nutrients under consideration, namely, potassium, calcium, magnesium, phosphate and sulfate.

2. The soluble mineral nutrient distribution in the peanut plant is shown graphically. The leaf blades, petioles, and stems, respectively, were separated into top, middle, and lower portions. The range in concentration of mineral nutrients in the respective parts of peanut plants grown in various fertilizer field experiments are shown.

3. The plants were analyzed at three stages of growth, namely, vegetative, early fruiting, and at maturity. The vegetative stage is the most practical for foliar diagnosis as fertilizer supplements may be beneficially applied as top or side dressings during this stage.

4. The lower blades of the peanut are the most suitable portions to test for all mineral nutrients in determining deficiencies or excesses in the plant with special reference to calcium, potassium, and magnesium.

5. There is a relation between the mineral nutrient concentration in the lower blades of the peanut plant and fertilizer treatment and response.

6. The calcium-potassium relationship is an important factor associated with the growth and yield of peanuts under the conditions of these experiments in the Coastal Plain region of North Carolina.

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THE GENETICAL BEHAVIOR OF THREE VIRESCENT MUTANTS IN ASIATIC COTTON[1]

CHI-PAO YU[2]

MUTATIONS affecting the chlorophyll content in cotton are not uncommon. They can be classified into at least three categories according to the extent of chlorophyll. In the first place, there is the yellow seedling which has no trace of chlorophyll, as reported by Stroman and Mahoney (6),[3] Feng (1), Hutchinson and Nath (4), and the writer (7). Lacking the assimilating pigments, the young yellow seedling plant cannot survive. The inheritance of this character is genic.

Variegated leaf is the second category which includes the type having leaves with areas of different shades, such as reported by Harland (3), and another type, often occurring in Chinese cotton, having leaves with portions of green and white. Harland concluded that the former type is inherited through the genes, but the latter type shows maternal inheritance.[4]

The third kind is virescent. Here the seedling contains less chlorophyll than normally, but the content increases gradually as the seedling grows. However, the shade of the virescent plant shows less green in the mature stage than normal plants. The characters, reported by Killough and Horlacher (5) and by the writer (8), belong to this category and their inheritance is genic. The mutants reported here are of a virescent nature.

The three mutants occurred successively in 1935–37. Previously, the writer obtained a virescent bud designated v_1. According to the order of their occurrence, the present three mutants are called v_2, v_3, and v_4. Their expressions are not only different from the previous one, v_1, but they are easily differentiated between themselves. The characteristics of the v_1 are its virescent bud and young leaves, which become green as the plant grows. The v_2 has its individuality of virescent shoot, which deepens very slightly and slowly. The v_3 shows less green than the normal plant, but more green than the v_2. The change of color in v_3 is more prompt than in v_2. At first sight the v_4 seems light green, but, after careful examination, one can see numerous green droplets distributed evenly on the entire leaf. The droplets are so small that they are not easily detected by naked-eye observation. With v_4 plants, no marked change of color occurs throughout its life. The differences between these four types are distinct enough for one to classify them conveniently at the mature stage, though it is not so easy when they are very young. In two pure lines of "Shaokan Long Staple", mutants v_2 and v_4 were obtained and the latter has appeared twice. Mutant v_3 was discovered by one of the writer's co-workers, L. C. Hsien, in another pure strain.

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[1]Contribution from the National Central University, Chungking, China. Received for publication April 5, 1941.

[2]Professor. The writer is indebted to Dr. C. Y. Chou who kindly read the manuscript.

[3]Figures in parenthesis refer to "Literature Cited", p. 758.

[4]Personal communication from C. C. Feng.

Tables 1, 2, and 3 show the inheritance of v_2, v_3, and v_4, the relationships between them, and the results of the linkage test with other characters.

The figures in Table 1 show clearly that the three mutants are of Mendelian inheritance.

There are six possible combinations between the four virescent mutants, but only two of them are studied here. The v_1v_2 set is counted at seedling stage when the V_1v_2, v_1V_2, and V_1V_2 cannot be classified. It is evident that v_1 and v_2 are inherited independently, and further, that they are complementary factors.

EXPERIMENTAL RESULTS

TABLE 1.—*The inheritance of the virescent character in the F_2 generation.*

Families	Dominant	Recessive	Deviation	X^2	P
V_2, v_2	44	20	4	1.3	>0.20
V_3, v_3	26	13	3.25	1.4	>0.20
V_4, v_4	40	9	3.25	1.2	>0.20

TABLE 2.—*Relationship between the virescent mutants as revealed in the F_2 generation.*

Combinations	XY	Xy	xY	xy	Dev.	X_2	P
V_1v_1; V_2v_2	66	—	52	—	0.4	—	—
Cal. (9:7)	66.4	—	51.6	—	—	Small	Large
V_3v_3; V_4v_4	17	7	4	3	—	—	—
Cal. (9:3:3:1)	17.5	5.8	5.8	1.9	—	0.3*	>0.8

*The third and fourth terms are combined in calculation.

TABLE 3.—*Results of linkage test with other characters in the F_2 generation.*

Combinations	XY	Xy	xY	xy	X^2	P
Anthocyanin: v_4	32	6	8	3	1.9	>0.30
Cal. (9:3:3:1)	27.6	9.2	9.2	3.0		
Corolla: v_4	27	7	6	1	1.7*	>0.30
Cal. (9:3:3:1)	23.1	7.7	7.7	2.5		
Curly leaf: v_4	34	8	5	2	4.0*	>0.10
Cal. (9:3:3:1)	27	9	9	3		

*The third and fourth terms are combined in calculation.

In the v_3v_4 set, the segregated classes can be distinguished clearly even at a very young stage. The numbers of the third and fourth classes, however, are not sufficient for calculation, according to Fisher (2), therefore, the two classes are combined for calculating the X^2 value. The results show that they are independently inherited. Whether linkage relations exist between v_1,v_2, and v_3,v_4 is not known. Further, it may be suspected that the former two genes are the same as the latter two; but according to their expressions, it seems that this is not the case.

The linkage relations of v_2, v_3, and other characters have not been studied. Table 3 shows the relationships between v_4 and three other characters. The results show that the v_4 is not linked with the anthocyanin pigment, corolla color, and the curly leaf, a mutant gene in Asiatic cotton (8).

SUMMARY

The virescent genes v_2, v_3, and v_4 occurred in pure lines of Asiatic cotton, and the v_4 appeared twice. Their expressions are different.

The mutant genes with their allelomorphs show simple Mendelian inheritance.

The v_1 and v_2 are two different genes. They segregate independently and are complimentary factors. The v_3 and v_4 are also two different genes that segregate independently.

The v_4 shows independent inheritance with genes for the anthocyanin pigment, corolla color, and curly leaf.

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THE USE OF TETRACHLORETHANE IN THE ERADICATION OF THE EUROPEAN BINDWEED[1]

A. L. Bakke[2]

SMALL amounts of chlorine (4),[3] acetylene (1, 5), and ethylene (3) have been known to be toxic to plants. This fact suggested that tetrachlorethane, which is made from chlorine and acetylene and gives off ethylene, might prove to be effective in destroying the European bindweed, *Convolvulus arvensis* L. In many states this plant (2) is considered to be the most serious of all weeds and its immediate eradication is a serious problem. It seemed probable that if the deeply penetrating roots of the European bindweed were subjected to highly toxic vapors of tetrachlorethane, the undesirable growth would be destroyed. The experimental evidence presented in this paper shows how tetrachlorethane may be used in the eradication of the European bindweed.

Tetrachlorethane, $CHCl_2.CHCl_2$, known also as acetylene tetrachloride and tetrachloride of ethylene, is obtained by the addition of chlorine to acetylene in the presence of iron as a catalyst. A direct union of these two gases would cause an explosion. Tetrachlorethane is a colorless, non-inflammable liquid with a distinct but not disagreeable odor, insoluble in water, and soluble in alcohol and ether. It has a boiling point of 146.3° C, is strongly resistant to cold, solidifies at a temperature of –43.6° C, has a specific gravity of 1.595, and weighs 13.31 pounds per gallon.

Tetrachlorethane[4] is attacked by alkaline solutions which convert it into trichlorethylene. It is not appreciably attacked by the metals, but in the presence of sufficient moisture enters into a reaction with them to form dichlorethylene. Tetrachlorethane is also used as an insecticide.

All chlorinated hydrocarbons are toxic to animal life. Human beings should not be exposed for an extended period of time in a place where the vapor of the chlorinated hydrocarbons is detectable. Such exposures constitute a health hazard. Tetrachlorethane is absorbed mainly through the lungs, but sufficient quantities may be absorbed through the skin to cause complete necrosis. Repeated exposure to low concentrations may produce cumulative physiological effects such as liver injury. Contact of the skin with any of the chlorinated hydro-

[1]Journal Paper No. J-874 of the Iowa Agricultural Experiment Station. Project 484, in cooperation with the Division of Cereal Crops and Diseases Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication April 23, 1941.

[2]Research Professor, Iowa Agricultural Experiment Station and Collaborator, U. S. Dept. of Agriculture. Grateful acknowledgement is made to E. I. DuPont de Nemours and Company Inc., Wilmington, Del., for furnishing the tetrachlorethane used in the investigations reported in this manuscript. Thanks are also due T. Coyle and E. W. McGovern of that company for furnishing special literature on the subject.

[3]Figures in parenthesis refer to "Literature Cited", p. 760.

[4]R. & H. Technical Bulletin, Issued by the R. & H. Chemicals Department, E. I. DuPont de Nemours and Co. Inc., Wilmington, Del.

carbons or their vapors should be avoided because absorption through the pores of the skin may produce the same physiological effects as inhalation. They may produce excessive dryness and subsequent cracking of the skin due to the extraction of the natural oils present. When minor contact is unavoidable, the skin may be protected by DuPont's "Protek". Lanolin preparations may be used to replace the natural oils extracted from the skin.

According to von Oettingen (6), first symptoms consist of headache, dizziness, nausea, and vomiting. The person afflicted should be brought into a place where there is proper ventilation. Alkaline chlorides should be consumed in liberal amounts to increase diuresis.

In 1937, 1938, and 1939 experiments with tetrachlorethane were conducted upon the grounds and fields of the State Hospital, Cherokee, Iowa, where there was a heavy infestation of European bindweed. Holes 18 inches deep and 18 inches apart were made by driving discarded automobile axles sharpened to a point. The holes were staggered to increase penetration of the toxic gases. Two ounces of tetrachlorethane were poured from a tea kettle into a small graduate and the contents of the graduate emptied into each hole through a funnel with a stem 12 inches long. Shortly after the addition of the tetrachlorethane, the holes were filled with fertile soil and vigorously tamped to seal the openings. In 1938, a "hand prod" set furnished by Wheeler, Reynolds, and Stauffer Co.[5] was used in making the injections, but in 1939 the "Economy Carbo Injector" manufactured by the same company was used.

The European bindweed was completely eradicated in all the tetrachlorethane experiments, which involved more than 20 square rods, in 1937 the treatments were made in August, while in 1938 and 1939 they were made in November. Plots treated in November and sown with millet the following June produced practically a normal crop. Bluegrass on lawns that were treated with tetrachlorethane showed deleterious effects the next season, but these effects did not prove to be permanent.

The amount of tetrachlorethane used to date has been 2 ounces to each hole, 18 inches deep and 18 inches apart. Smaller amounts of the chemical are not sufficient to kill all the bindweeds.

The experimental work reported shows that tetrachlorethane may be used effectively in eradicating the European bindweed. Because of the labor involved, however, the method can be recommended only where immediate eradication is desired. At the present time the cost is prohibitive on large areas.

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[5]This San Francisco company has developed an injector for carbon disulfide that may be used for tetrachlorethane.

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BOOK REVIEW

CONSERVATION OF RENEWABLE NATURAL RESOURCES

Edited and published by the University of Pennsylvania Press. Philadelphia, Pa. VI + 200 pages, illus. 1941. $2.50.

THIS book, a product of the University of Pennsylvania Bicentennial Conference, is compiled by a group of forest, botanical, geographical, meterological, and conservation authorities. It is made up of three major sections with four contributors to each section as follows:

1. The Natural Vegetation of the United States as a Guide to Current Agricultural and Forestry Practice, by Raphael Zon, William S. Cooper, Gustaf A. Pearson, and Homer L. Shantz.

2. Climatic Cycles in Relation to the Theory and Practice of Conservation, by A. E. Douglass, Charles G. Abbot, Paul B. Sears, and Ellsworth Huntington.

3. The Administrative Task of Conservation—Private and Public, by Morris L. Cooke, Samual T. Dana, Milton S. Eisenhower, and Julian F. McGowin.

The book deals with a wide range of the more fundamental and broader aspects of conservation, such as native vegetation and the changes brought about by man's occupancy of the land, climatic cycles and their effect on man and his environment, and conservation from the standpoint of the state and federal governments.

The whole book makes interesting reading both for the layman and the scientist. (R. C. C.)

AGRONOMIC AFFAIRS

JOINT COMMITTEE ON MEASUREMENT OF SOIL TILTH

MR. Raymond Olney, Secretary of the American Society of Agricultural Engineers, has notified Dr. G. G. Pohlman that the following members of his Society have been named on a committee on Measurement of Soil Tilth to act with a similar committee from the American Society of Agronomy: L. F. Reed, P. O. Box 792, Auburn, Alabama, *Chairman;* M. L. Nichols, Soil Conservation Service, Washington, D. C.; G. D. Jones, Cleveland Tractor Co., Cleveland, Ohio; and B. A. Jennings, Department of Agricultural Engineering, Cornell University, Ithaca, New York.

Members of the Soil Tilth Committee of the American Society of Agronomy are L. D. Baver, Agricultural Experiment Station, Raleigh, North Carolina, *Chairman;* J. F. Lutz, North Carolina State College, Raleigh, North Carolina; H. E. Middleton, Soil Conservation Service, Washington, D. C.; and R. J. Muckenhirn, University of Wisconsin, Madison, Wisconsin.

ABSTRACTS OF PROGRAM PAPERS

MENTION was made in the June number of the JOURNAL that abstracts of papers to be presented before the several Sections of the Soil Science Society would be made available in mimeographed form in advance of the meetings through Doctor Pohlman's office at the West Virginia Agricultural Experiment Station, Morgantown, W. Va., at a cost of 10 cents to cover mailing charges.

Announcement has now been made by Dr. C. J. Willard, Chairman of the Crops Section of the American Society of Agronomy, that mimeographed abstracts of papers to be delivered before the Crops Section will also be available prior to the meeting and may be obtained for 10 cents upon application to Doctor Pohlman.

All persons who are planning to present papers before the Soil Science Society or the Crops Section of the American Society of Agronomy are urged to submit abstracts to the various program chairmen at once.

THE 1941 MEETING OF THE WESTERN SECTION OF THE SOCIETY

THE annual meeting of the Western Section of the American Society of Agronomy was held in Corvallis, Oregon, June 12 to 14. The attendance was in excess of 50 from seven western states. Dr. O. S. Aamodt of the Division of Forage Crops and Diseases, Dr. S. C. Salmon of the Division of Cereal Crops and Diseases, and D. E. Stephens, coordinator between the Bureau of Plant Industry and the Soil Conservation Service, were present from Washington, D. C.

The program for this meeting was built around discussion groups and a few papers rather than on the usual plan of presenting formal papers only. The discussion topics included range problems, with E. R. Jackman as leader; new forage crops, with H. A. Schoth as leader; soil problems, with R. E. Stephenson as leader; soil conserva-

tion problems, with S. R. Sloan as leader; and breeding problems, with O. S. Aamodt and R. E. Fore as leaders. The discussion periods were well received and it was the general consensus of the group that they provided a welcome addition to the program.

Experimental work at Corvallis and at some outlying points was visited, and the last day was spent in inspecting the experimental work on cut-over lands in Clatsop County, the John Jacob Astor Branch Station at Astoria, and the sand dune control work in the soil conservation district at Warrenton, Oregon.

The 1942 meeting will be held in late July at Laramie, Wyoming. H. P. Singleton, Superintendent of the Irrigation Experiment Station at Prosser, Washington, was elected President of the Section to succeed A. H. Post of Montana, and Dr. G. H. Starr of the Wyoming Agricultural Experiment Station was elected Secretary.—D. D. Hill, *Secretary.*

NEWS ITEM

Dr. Richard Bradfield, head of the Department of Agronomy at Cornell University, was one of three experts sent by the Rockefeller Foundation to Mexico to study crop improvement for that country. The visit of the commission was the result of a suggestion by Vice-President Henry Wallace of the need for greater nutrition values in Mexican food.

ERRATUM

ATTENTION is called to an error in the article by V. C. Hubbard in the June number of the Journal entitled, "Irregular Germination of Wheat in a Dry Soil" in which Fig. 1 on page 578 is inverted, thus rendering the caption beneath the cut incorrect. The caption should be read with this error in mind.

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SOIL CHANGES ASSOCIATED WITH TILLAGE AND CROPPING IN HUMID AREAS OF THE UNITED STATES[1]

E. P. WHITESIDE and R. S. SMITH[2]

CHANGE in productivity of soils after periods of cropping and the relative ability of different crops to preserve, amend, or deplete the productiveness of a given soil have been observed from the earliest records of agriculture to the present day. In the United States, however, only within the last three-quarters of a century has there been an attempt to measure the actual alterations of soils that are associated directly or indirectly with cultivation and cropping practices. The investigation reported here deals with some differences between cultivated and uncultivated areas of a dark-colored prairie soil in Edgar County, Illinois. Mechanical analyses, total carbon, base exchange capacity, and total exchangeable base determinations on four profiles of this soil are reported.

The change in total amount of a constituent in a soil system in unit time will be the difference between the gains and losses during the period. Under natural conditions additions may be due to sedimentation from the air and water moving across the surface; return of plant and animal tissues and excretions; precipitation of moisture carrying dissolved minerals, dissolved gases, or solid particles; and absorption of materials from the atmosphere. Removals from the soil are due to losses in solution or suspension by leaching and erosion, volatilization, and uptake of nutrients by the plant and animal life associated with it. When considering only a portion of a soil system, movements of materials within the system by plants, and animals, as gaseous or liquid solutions or suspensions, and migration along surfaces become further modes of change. The net result may be either a gain or loss of a given constituent. The introduction of tillage and cropping practices, without use of fertilizers, brings in no additional known mode of gain or loss to the soil system but rather an alteration of the relative amounts or rates of addition to and removals from the soil. Tillage operations become an additional method of movement within the soil body.

[1]Contribution from the Department of Agronomy, Illinois Agricultural Experiment Station, Urbana, Ill. Published with the approval of the Director. Received for publication March 24, 1941.

[2]Associate in Soil Survey and Professor of Soil Physics, respectively.

Changes in other than total composition may result from tillage and cropping and are frequently very important. Samples taken for the study of total composition may ordinarily be used in estimating other chemical, physical, and biological changes.

Jenny (22)[3] has presented data to show the relationship between climate (temperature and humidity) and the average organic matter and nitrogen content of cultivated surface soils similar in texture and developed under similar vegetative covers. In the humid regions studied, the average nitrogen content of originally timbered soils was less than for prairie soils in the same climatic conditions. In both groups the nitrogen content decreased exponentially with increasing temperature when humidity was constant, and increased with increasing humidity when the temperature remained constant. He also pointed out a direct linear relationship between average nitrogen content of the soil and average corn yields in bushels, south of northern Iowa. With lower temperatures in Minnesota and North Dakota, Jenny found that the nitrogen content of the soil continued to increase, but corn yields decreased, apparently because the cool climate becomes the limiting factor in corn grain yields.

REVIEW OF LITERATURE

The following review of literature dealing with soil changes related to tillage and cropping includes only some of the work with soils in regions having N. S. Q. values > 280 as given by Jenny.

Total nitrogen and organic matter decreases in the surface of tilled soils relative to adjacent long untilled timber or grassland areas have frequently been reported (7, 13, 20, 21, 25, 26, 30, 38, 43, 44, 50, 51, 52, 56, 58). The losses found in the surface soil usually vary from 25 to 50%. Smaller percentage decreases of these constituents have been noted in the subsurface horizons (20, 38, 44, 51). That these differences are at least partly due to decreases of these constituents in cultivated areas where cropping systems not including a sizeable portion of sod or legume crops were used has been shown by a number of investigators working with plots which were sampled more than once during the period studied (12, 28, 37, 43, 45, 46).

The cropping system used has a very great influence on the amount and direction of the change in nitrogen and organic carbon of the soil. Intertilled crops generally show greatest decreases, cereal crops less, and legume and sod crops least. Increases or little change in nitrogen or organic carbon have frequently been noted under sod or legume crops or in systems where these crops occupied the land a large proportion of the time, with or without manures (12, 16, 23, 28, 34, 36, 37, 43, 45, 46). All of the plots discussed in the above papers, with the possible exception of those reported by Shutt (43), apparently had been cultivated prior to the establishment of the cropping and management systems studied. Jenny (21) presented data on grassland soils of the Middle West to show that the decrease in nitrogen of surface soils, with common cropping practices, was most rapid in the first few years and later became stabilized at a level depending upon the cultural system employed with a given soil type in a given environment. Snyder reported (45) that crop removals accounted for only about one-fourth or

[3]Figures in parenthesis refer to "Literature Cited", p. 775.

one-fifth of the nitrogen lost in oats, barley, or wheat plots and for about four-fifths of the loss in a 5-year rotation.

Salter and Green (37) and Metzger (28) have both observed a direct linear relationship between total carbon and nitrogen and total crop production on given soil types. The Morrow Plots at Urbana, situated on a soil very similar to the one studied in the present investigation, show a fairly close linear relationship between the average total carbon content of the surface soils in 1913, 1923, and 1933 (12) and the average corn yields (4) for the six years between 1907 and 1937 when all the plots were in corn.

Recently, Wheeting (54) worked with 73 pairs of samples including seven coarse-textured soil series from adjacent cutover and cultivated fields in a coniferous forest area in western Washington (55). The cultivated soils had been cropped 2 to 46 years, mainly to cereals, grasses, and rotations with and without manures and fertilizer. All land had been subjected to compulsory slash burning following clearing. He concluded there was an average increase of organic matter in cultivated fields of 1.27% or about 28% of the original content and of about 50% of nitrogen in the seven pairs of samples analyzed for this element. Nitrification during a 30-day period he found was greater in cultivated soils. Under the better systems of soil management, Wheeting says these western Washington soils have maintained superiority over virgin soils for at least a 45-year period. This behavior, he suggested, was due to the change in type of vegetation and a climatic environment different from that of forested regions in eastern United States.

Ammonia-soluble organic matter determinations generally have shown trends similar to the organic carbon and nitrogen (45, 53) with cultivation. Decreases in nitrogen, phosphorus, and bases associated with the humus of cultivated soils compared to those under nearly virgin conditions have been noted by Snyder (44), M'Guigan (30), and Schollenberger (38).

Swanson and Miller (52) in Kansas, Shedd (42) in Kentucky, and Hart and Peterson (18) in Wisconsin have all reported about 40% less total sulfur in the surface of cultivated soils receiving little or no manure than in adjacent virgin areas. Hart and Peterson found that heavily manured cultivated soils on the average showed a higher sulfur content than the virgin areas. Shedd also reported decreases in the subsurface horizon.

Working with virgin and cultivated soils, Swanson and Latshaw (51), Schollenberger (38), and Whitson and Stoddart (57) concluded that losses of phosphorus occur on cropping with little or no manure additions. Swanson and Latshaw noted a relatively small removal of phosphorus from the surface soil by alfalfa and Shedd (42) and Dorman (13) found no significant changes in total phosphorus in soils with cultivation.

Much of the work on the influence of cultivation on the total Ca and Mg in soils, only two studies of which are reported here, seems inconclusive. Ames and Schollenberger (2) concluded there was no general relation between total calcium and magnesium content of virgin and cultivated soils in Ohio. They point out the large variation within a soil type. Shedd (40) studied 34 pairs of virgin and cultivated soils and concluded that in nearly every instance cultivation had resulted in a decrease of calcium. Shedd (41) found that 20 of 30 cultivated surface soils and 15 of 23 subsurface samples showed smaller amounts of manganese than adjacent virgin areas.

The variable results in total chemical analyses of inorganic soil constituents noted above may be expected because of the original variability of the soils

vertically and horizontally. The experimental errors in usual total chemical analyses exceed the amounts of minerals removed in 50 grain crops, assuming all the nutrients were removed from the surface 6 inches of soil and legumes are grown infrequently. Loss of organic constituents tends to increase the proportion of inorganic materials present.

Millar (31) noted a lower rate of solubility in water of cultivated surface soils than virgin soils, measured by the freezing point method. Subsoils showed no difference in rate of solubility. The difference in rate of solubility of surface soil, he found, persisted after organic matter removal with hydrogen peroxide.

Base exchange studies of virgin and cultivated soils have been reported by Jenny (21), Auten (3), and Dorman (13). Jenny found 33% less total exchangeable bases in a Putnam silt loam when cultivated over 60 years to wheat, oats, and corn with no fertilizer or manure applications than in a virgin prairie area. Auten concluded there was considerably less exchangeable calcium and magnesium in the A_1 horizon of cultivated fields than adjacent old growth timber and a tendency for these to increase in the A_2 horizon. He compared A_1 horizon samples taken 0 to 4 inches deep in woods and 0 to 6 inches deep in adjacent fields. Dorman reported no consistent change in exchange capacity or exchangeable bases with cultivation. Two pairs of samples from the same soil type showed almost exactly opposite trends with cultivation.

Merkle (27) reports less exchange capacity and exchangeable bases in the Jordan field check plots of Pennsylvania than in the grass borders. He noted little difference in exchangeable K, Na, or H but less exchangeable Ca, Mg, and NH_4 in the cultivated plots.

Schollenberger and Dreibelbis (39) noted decreases in exchangeable calcium, magnesium, potassium, sodium, and total exchangeable bases (including hydrogen) in Wooster silt loam, during 31 years cropping, using a 5-year rotation without fertilizer or lime applications. The amount of exchangeable hydrogen increased.

Wilson (59) found five of six unfertilized soils decreased in exchangeable Ca and all six decreased slightly in exchangeable K content of the upper 12 inches during 15 years of cropping in metal cylinders to a fodder corn-timothy-barley-clover rotation. Soils were sampled at the beginning and end of the experiment and leaching was permitted throughout the period.

Prince, *et al.* (34) found plots cropped to a corn-oats-wheat-timothy (2 years) rotation from 1908 to 1937 to be lower in N, C, pH, exchange capacity, and total exchangeable bases than a plot allowed to grow up in grass and weeds for this period. Since first sampled in 1913, the cultivated field had decreased and the uncultivated increased in carbon and nitrogen. All plots receive fertilizers, cultivated and uncultivated plots receiving equal applications.

Snyder (44), M'Guigan (30), and Jenny (21) report less favorable moisture conditions in cultivated than virgin prairie soils. Free (15), working with Marshall silt loam, found less runoff and percolation from sod than from corn plots, but also a lower average moisture content during the three years 1933 to 1935. Snyder reported that the moisture content of continuous wheat plots in Minnesota was less favorable during dry seasons than a rotated wheat plot or one receiving an application of well-rotted manure early in the season. Corn land, he found, had a higher moisture content than wheat plots during dry periods. Stauffer (47) found the water-holding capacity of the Morrow Plots at Urbana, Illinois, to increase with organic carbon content of the surface soil (0 to 6⅔ inches). He also presented data for 6⅔ to 13⅓ and 13⅓ to 20 inch layers.

Water and soil losses by runoff and erosion from plots under different tillage and cropping systems on Shelby loam at Columbia, Missouri, during a 14-year period are reported by Miller and Krusekopf (32). They found total runoff and erosion losses followed the order fallow (plowed 4 or 8 inches deep) > continuous corn > continuous wheat > corn-wheat-clover rotation > bluegrass sod. Losses of total nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur in the eroded material from these plots from May 1, 1926, to May 1, 1928, follow this same order. The total erosion and runoff losses from continuous corn were much greater than corn in rotation for 6-month periods when the rotation plot was in corn. Investigations of Free (15) and Hide and Metzger (20) dealing with runoff and erosion losses have already been mentioned.

Variations of soil temperature at different depths when bare or under different vegetative covers have been reported (36, page 511; 24, page 300; 6; 5, page 270). While the changes noted are usually small, the nitrogen-temperature and organic matter-temperature relations of Jenny (22) indicate it may be significant, because of the exponential nature of the function, in determining the change in these constituents in soils with cultivation and different vegetative covers. The temperature in the surface of bare or cultivated plots is higher in summer than sod or timbered areas. The difference decreases with increasing depth.

Calcium, potassium, magnesium, and sulfur lost by leaching were in proportion to the amount of drainage water in lysimeter investigations at the University of Illinois (62). Leaching was reported to be greatest in bare ground followed in order by corn, small grain, clovers, and alfalfa plots. Russell (36, page 376) reports less percolation and leaching from cropped than from barren soil. Free (15) reported less percolation from bluegrass than from a corn plot at Clarinda, Iowa.

Snyder (44; 45, Bul. 53) reported the volume weights of surface soil in cultivated fields were greater than in adjoining uncultivated areas and that continuous grain plots averaged higher in volume weight than rotated plots.

Bradfield (7) reported greater volume weight and smaller pore space in the upper 3 feet of a tilled compared to a virgin area. Stauffer, *et al.* (48) have reported the average volume weights in the surface 0 to 6 inches of unfertilized Morrow Plots to be in the order continuous corn > corn-oats rotation > corn-oats-clover rotation > sod border though the differences were said not to be significant.

Aggregate analyses by Jenny (21) showed a decrease in particles of sand size and an increase of clay-size particles in a cultivated field compared to untilled Putnam silt loam. Browning (11) found more large aggregates and less small aggregates in a sod plot of DeKalb silt loam than in a cultivated area of the same soil. Organic matter content of the two areas was 3.5 and 2.0%, respectively. Stauffer, *et al.* (48) found the percentage of total aggregates > 0.05 mm in diameter were greater in surface samples from the sod border than from cultivated plots. Detailed aggregate analyses of the plots at four depths above 18 inches are presented. The corn-oats-clover rotation plot fertilized with manure, lime, and rock phosphate showed considerably more total aggregates than the other plots. They found large differences in organic carbon content of the cultivated plots made little difference in total aggregates. Metzger and Hide (29) have also reported studies of the effect of certain crops on soil aggregation.

Eluviation of fine material and its deposition at just below plow depth has commonly been offered as an explanation of the "plow sole." Bray (8) found a larger amount of superfine colloid in the surface of a grass border than in adjacent continuous corn plots and concluded that this quantity of superfine colloid had moved out of the surface of the cultivated plot. He has more recently repeated

this work, including samples immediately below the plow depth and using a more accurate method. These results, he found, fail to show the previously suggested eluviation and "plow sole" formation (9). Shaw (1) contends that in certain orchards observed, "plow sole" was formed by compaction when ground was worked at too high a moisture content. Hester and Shelton (19) have recently reported the most deleterious effect of cultivation and fertilization of some truck soils in Virginia is due to the movement of clay from the topsoil to the subsoil. This has been enhanced by use of Na-bearing fertilizers but is counteracted by gypsum additions.

EXPERIMENTAL

To the authors' knowledge, no previous study of adjacent virgin and cultivated prairie soils has been reported from Illinois. Therefore, when they learned of a fairly large track of land which had never been tilled adjacent to one farmed intermittently since the late 1850's,[4] a preliminary investigation was begun. Four detailed profiles were taken with a spade within an area of 0.1 acre. Two were in the unbroken prairie (virgin) which had been pastured and two in the cultivated field just across the fence. There were no roads closer than 80 rods.

The base exchange capacity (33), total exchangeable bases (10), total carbon (61), and mechanical composition (60) of all samples were determined. The data with locations and profile descriptions are given in Tables 1 and 2. Mechanical analyses by the method of Steele and Bradfield (49)[5] with and without hydrogen peroxide pretreatment and base exchange capacity before and after hydrogen peroxide treatment are given for some of the samples in Table 3.

DISCUSSION

The mechanical analyses of the profiles (Table 1) indicate considerable original variation within the soil area and no consistent trend that could be attributed to the effects of tillage and cropping on the soil. Comparison of the fractions less than 1μ by a modification of the Steele and Bradfield method before and after hydrogen peroxide treatment for samples 14948 to 14953 (Table 3) indicate a considerable dispersing action with the peroxide treatment as shown by

[4]The authors are indebted to D. D. Baber, owner of this property, for permission to obtain these samples and for the following brief history of the fields: The cultivated field was broken from prairie sod in the late 1850's for corn. During the Civil War it was in wheat, and when wheat prices declined it went back into grass. In 1875 the land was plowed and two crops of corn produced, the stalks were then burned, and the field sown to oats and timothy. Several crops of hay were harvested, then redtop came in and the field was permitted to return to grass. From 1927 to 1933 it was again cropped to corn; in 1934, to wheat; and in 1935, to corn. No fertilizer has been applied and stalks have been plowed under. No feeding bunks or straw stacks have ever been near the spot investigated. The adjoining pasture has not been plowed. The samples were taken in October, 1935, with the assistance of Herman Wascher and R. S. Stauffer.

[5]Exchangeable bases were removed by leaching with 0.1N HCl in place of electrodialysis and NaOH equal to the base exchange capacity was added to disperse the soil. Forty m.l. of 11% hydrogen peroxide, with 5 grams of soil, were used prior to acid leachings in peroxide treated samples. A check of a few samples indicated about 80% of the organic carbon was removed with peroxide.

the higher percentages of these fractions in spite of the removal of organic materials soluble in the dispersing agent. This may be due to the removal of organic materials which bind primary particles together, to the action of heat on aggregates, or possibly to the mechanical action of the hydrogen peroxide on the primary or secondary particles, as shown by Drosdoff and Miles (14). That the action is primarily on the organic materials may be indicated by the greatly decreased effect in the B horizon of this profile, although mineralogical differences may also play a part. Most of this dispersing action in the A horizon is shown in the $<.125\mu$ fraction. Robinson (35) and Winters and Harland (60) have reported similar results of peroxide treatment, although the latter authors working with soils lower in organic matter thought the effect too small to be significant.

TABLE 1.—*Mechanical composition of virgin and cultivated soil profiles of Flanagan silt loam* in Edgar County, Illinois.*

Horizon	Virgin					Cultivated				
	Depth, in.	Lab. No.	Per cent			Depth, in.	Lab. No.	Per cent		
			Sand	$<5\mu$	$<1\mu$			Sand	$<5\mu$	$<1\mu$
A_1	0–2	14948	17.6	30.6	13.9	0–2	14972	20.4	28.1	15.3
	2–5	14949	19.2	27.9	11.8	2–5	14973	20.6	29.2	15.8
	5–9	14950	14.8	27.5	11.7	5–8	14974	21.0	27.9	12.1
A_2	9–12	14951	13.9	28.9	13.5	8–11	14975	21.3	28.0	12.6
	12–15	14952	12.3	30.8	15.6	11–14	14976	20.4	27.8	13.2
B_1	15–18	14953	9.1	34.4	19.8	14–17	14977	14.6	31.5	16.6
B_2	18–21	14954	3.6	47.2	29.8	17–20	14978	8.3	39.1	23.4
	21–24	14955	3.0	43.0	31.6	20–23	14979	4.3	46.1	32.0
	24–27	14956	3.1	41.6	29.8	23–26	14980	3.6	46.9	33.5
	27–31	14957	3.7	36.7	27.4	26–32	14981	2.6	44.3	32.0
C	31–37	14958	4.3	29.2	20.8	32–38	14982	5.1	33.8	23.8
	37–43	14959	16.3	24.8	16.2	38–44	14983	1.1	29.8	20.4
A_1	0–2	14960	17.3	29.4	13.7	0–2	14984	24.7	26.8	15.2
	2–5	14961	17.9	29.2	13.6	2–5	14985	24.8	27.2	15.7
	5–8	14962	19.9	29.2	14.9	5–8	14986	26.4	26.9	13.5
A_2	8–11	14963	18.0	28.7	14.9	8–11	14987	26.8	26.5	14.0
	11–14	14964	18.5	28.1	13.4	11–14	14988	27.7	26.6	13.2
B_1	14–17	14965	17.6	28.3	15.1	14–17	14989	19.6	31.2	17.5
B_2	17–20	14966	13.4	33.8	20.2	17–20	14990	7.3	39.3	25.3
	20–23	14967	10.3	39.9	27.5	20–23	14991	3.7	42.3	28.9
	23–26	14968	8.2	43.7	31.8	23–26	14992	2.2	41.4	29.5
	26–32	14969	7.3	43.4	31.1	26–32	14993	2.6	38.1	27.4
C	32–38	14970	7.1	39.6	28.0	32–38	14994	2.5	36.2	26.3
	38–44	14971	11.3	31.5	21.6	38–44	14995	9.0	28.9	18.5

*Tentative correlation. For a description of this soil type see Ill. Soil Sur. Report No. 67. Samples were taken from N.W. ¼, Sec. 24, T. 13 N., R. 14 W. of 2nd P.M.

The effect of mechanical analysis procedures on the results obtained is shown in the comparison of cultivated and virgin profiles (Tables 1 and 3). The greater dispersing effect shown by the Steele and Bradfield method with peroxide treatment compared to the Winters and Harland procedure is less in the surface of the cultivated

TABLE 2.—*Base exchange capacity, exchangeable bases, percentage saturation, and total carbon of cultivated and virgin soil profiles of Flanagan silt loam* in Edgar County, Illinois.*

Horizon	Virgin						Cultivated					
	Depth, in.	Lab. No.	Base capacity	Exch. bases	% base saturation	Total % carbon	Depth, in.	Lab. No.	Base capacity	Exch. bases	% base saturation	Total % carbon
A_1	0– 2	14948	22.8	16.2	71.0	4.01	0– 2	14972	18.3	9.9	54.4	2.60
	2– 5	14949	21.9	16.6	75.9	3.25	2– 5	14973	17.8	10.2	57.5	2.53
	5– 9	14950	19.4	14.3	74.0	2.69	5– 8	14974	17.6	10.7	60.8	2.25
A_2	9–12	14951	17.5	13.3	76.0	2.00	8–11	14975	17.4	10.6	60.9	1.88
	12–15	14952	17.3	13.3	76.9	1.47	11–14	14976	16.4	9.6	58.5	1.63
B_1	15–18	14953	20.7	16.6	80.2	1.10	14–17	14977	18.4	11.8	64.1	1.22
B_2	18–21	14954	30.4	22.1	72.7	0.81	17–20	14978	24.5	16.1	65.9	0.91
	21–24	14955	30.2	23.5	77.8	0.61	20–23	14979	32.3	21.8	67.4	0.69
	24–27	14956	28.7	23.4	81.6	0.52	23–26	14980	35.3	26.3	74.5	0.54
	27–31	14957	25.2	23.0	91.3	0.40	26–32	14981	33.1	26.5	80.0	0.42
C	31–37	14958	19.4	18.0	92.8	0.29	32–38	14982	26.2	22.2	84.7	0.28
	37–43	14959	14.4	14.3	99.3	0.20	38–44	14983	21.8	21.8	100.0	0.21
A_1	0– 2	14960	26.0	14.9	57.3	4.20	0– 2	14984	16.9	9.3	55.3	2.52
	2– 5	14961	24.1	14.6	60.6	3.18	2– 5	14985	16.7	9.3	56.3	2.49
	5– 8	14962	22.1	13.0	58.8	2.60	5– 8	14986	16.3	9.4	57.6	2.07
A_2	8–11	14963	18.3	11.9	65.0	2.14	8–11	14987	15.0	8.8	59.0	1.62
	11–14	14964	17.0	10.9	64.1	1.74	11–14	14988	14.1	9.1	64.5	1.27
B_1	14–17	14965	15.9	10.3	65.1	1.37	14–17	14989	18.4	11.5	62.5	0.93
B_2	17–20	14966	18.3	12.5	71.0	0.96	17–20	14990	24.7	17.6	71.3	0.73
	20–23	14967	26.1	18.0	69.2	0.74	20–23	14991	28.0	21.1	75.3	0.61
	23–26	14968	30.4	22.5	74.0	0.62	23–26	14992	27.6	21.5	78.0	0.42
	26–32	14969	29.6	25.1	84.8	0.45	26–32	14993	27.4	21.3	77.7	0.40
C	32–38	14970	27.5	24.5	89.1	0.32	32–38	14994	24.1	21.9	91.2	0.34
	38–44	14971	21.9	19.6	89.5	0.31	38–44	14995	18.4	18.3	99.5	0.22

*See footnote of Table 1.

TABLE 3.—*Effect of hydrogen peroxide on mechanical composition and base exchange capacity of a virgin and a cultivated soil.**

Horizon	Depth, in.	Lab. No.	Base Cap. (no H_2O_2)	Base Cap. ($+H_2O_2$)	Mechanical analyses (Steele and Bradfield method)					
					No H_2O_2			After H_2O_2		
					$<5\mu$	$<1\mu$	$<.125\mu$	$<5\mu$	$<1\mu$	$<.125\mu$
					Virgin soil					
A_1	0–2	14948	22.8	12.1	32.8	13.3	7.2	28.9	19.0	11.8
	2–5	14949	21.9	11.5	30.5	14.5	7.6	29.0	19.0	12.0
	5–9	14950	19.4	10.9	30.8	12.6	6.5	29.3	18.8	11.8
A_2	9–12	14951	17.5	11.2	32.5	14.4	7.1	29.9	18.9	11.4
	12–15	14952	17.3	12.4	32.9	16.5	8.9	31.9	20.3	12.2
B_1	15–18	14953	20.7	15.3	38.1	23.4	11.8	36.2	23.6	13.0
					Cultivated soil					
A_1	0–2	14972	18.3	10.0	—	—	—	27.2	17.3	10.8
	2–5	14973	17.8	10.3	—	—	—	26.9	17.1	10.6
	5–8	14974	17.6	10.1	—	—	—	27.3	17.5	10.8
A_2	8–11	14975	17.4	10.4	—	—	—	28.3	17.5	11.2
	11–14	14976	16.4	10.8	—	—	—	28.9	18.3	10.5
B_1	14–17	14977	18.4	12.7	—	—	—	33.7	21.1	11.6

*All analyses based on weight of untreated oven-dry soil.

profile than in the uncultivated. This may be due to the lower organic content in the cultivated surface samples or possibly also to the mechanical mixing of the plowed layer. A greater uniformity in mechanical composition of the A horizons using the former method is apparent. There is no indication of a "plow sole" formed by movement of colloidal material in the cultivated profile.

The total carbon in this base unsaturated soil very closely approximates the organic carbon. The total carbon and base exchange capacity (Table 2) are both lower in the upper 8 to 12 inches of the cultivated than the virgin profiles. This seems to indicate a relation between organic matter and base exchange capacity. In order to test this indication, the organic matter was removed from the upper part of two of the profiles with hydrogen peroxide and the base exchange capacity re-run. The data in Table 3 show little difference in base exchange capacities of the cultivated and uncultivated A horizons after oxidation of the organic matter. The small difference is probably mainly due to variations in the physical composition. Organic matter is responsible for a large portion of the base exchange capacity in the upper part of this soil. Stauffer, *et al.* (48) also noted that where erosion was not a factor the differences in carbon content of a soil under various cropping systems were confined to the surface 9 inches. The loss of organic carbon with cultivation agrees with the results of other investigations of prairie soils previously cited.

The smaller content of exchangeable bases in the surface foot of the cultivated compared to the untilled soil represents an average of about 30% less of these mineral nutrients most available for plant growth (Table 2). This would be equivalent to about 8,000 pounds of pure limestone per acre, assuming an approximate volume weight of 1.28 as given by Harland and Smith (17) for Carrington and Muscatine silt loam in Champaign County.

The percentage saturation of the exchange complex (Table 2) shows no consistent difference between the cultivated and virgin samples. The virgin profile showing the smaller percentage saturation is underlaid by almost pure sand at 65 inches and is leached of carbonates to more than 75 inches. The other three profiles are calcareous at about 50 inches.

The smaller content of organic carbon, base exchange capacity, and exchangeable bases in the upper part of the cultivated soil is not believed to be very largely due to erosion since the soil is relatively flat and permeable. All these differences decrease with increasing depth and in general extend only about 1 foot beneath the surface.

SUMMARY

1. A review of some of the literature dealing with chemical and physical soil changes associated with tillage and cropping in humid areas of the United States is presented.
2. Mechanical analyses, total carbon, base exchange capacity, and exchangeable base determinations on adjacent tilled and uncultivated areas of a prairie soil are presented.

3. No difference in mechanical composition of virgin and cultivated profiles was observed, although considerable variation within the area was noted.
4. The tilled area has less organic carbon, base exchange capacity, and exchangeable bases in the upper 12 inches of the profile. The differences decrease with increasing depth. The smaller exchange capacity of the tilled soil is mainly due to a lower organic matter content.

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UPTAKE AND RETENTION OF WATER BY SOIL AS DETERMINED BY DISTANCE TO A WATER TABLE[1]

L. A. RICHARDS[2]

PROXIMITY of a water table definitely influences moisture relations in field soils, particularly as regards drainage problems. In a soil moisture system, the water table may be defined as the locus of points having atmospheric pressure. This corresponds to the height to which water stands in a test well, providing the water in the well and the water in the soil come to static equilibrium. For water in the soil at static equilibrium under gravity, the pressure in the water increases linearly with depth, being greater than atmospheric pressure below the water table and less than atmospheric pressure above the water table where, in general, the soil is not saturated. Taking atmospheric pressure as a reference value, the pressure in the water in unsaturated soil being less than zero is negative and is said to be under tension. The moisture content of unsaturated soil and the tension in the soil moisture are related in a general way.

Soils in the field, of course, seldom contain water which is at static equilibrium under gravity. It is possible, however, by use of porous ceramic cells to determine the moisture content that a given soil would have if it were a given distance above and were at static equilibrium with a water table. It is the purpose of this paper to present data showing the rate at which several soils would absorb water and equilibrium moisture contents that would be obtained at soil moisture tensions corresponding to various distances from a water table.

The relation between the moisture content of soil and the negative pressure in the soil water when graphically represented may be referred to as a moisture sorption curve and a variety of apparatus has been used for the determination of these curves for soils (2, 3, 8, 9, 10, 11).[3] Double-walled irrigator pots which were developed by the author for controlling moisture in plant experiments (3, 5) may also be used for obtaining moisture sorption data, as has been shown by S. J. Richards (8). Although the data here presented were obtained several years ago (1935–37), they appear to give new information on the time rate of approach to equilibrium in soil-wetting and drying processes.

APPARATUS

The apparatus arrangement is shown in Fig. 1. The container for the soil sample under study provides direct water connection between the soil-moisture system and a water supply at a lower level. The equilibrium tension of the water in the soil is set by adjusting the elevation of the free water table of the supply

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[2]Formerly Research Associate Professor of Soils and Associate Professor of Physics. Through the support of the National Youth Administration the author is indebted to Marvin Nelson, William Dickinson and Ray Kramer for assistance in obtaining the data reported in this paper.

[3]Figures in parenthesis refer to "Literature Cited", p. 786.

vessel. At any time the moisture content of the soil may be determined by weighing without disturbing a soil wetting or drying process.

The pots used[4] were of one piece construction, having a glazed outer wall ¼ inch thick, an unglazed inner wall ¼ inch thick, with an inter-wall space of ¼ inch for the supply water. The soil cavity is 6 inches in diameter at the top, 5 inches in diameter at the bottom and 6¾ inches deep. Any air accumulating in the pot was removed at the glass air trap before closing the pinch clamps and disconnecting the pot for weighing. The distance from the center of the soil mass down to the level of the water in the supply reservoir was measured by a steel tape, using a neon lamp to indicate contact of the tape with the water surface. Five of the units shown in the figure were set up in an interior room away from outside walls and the building heating system. Diurnal temperature fluctuations were of the order of 3° or 4°C and the maximum seasonal temperature range was from 21° to 31°C.

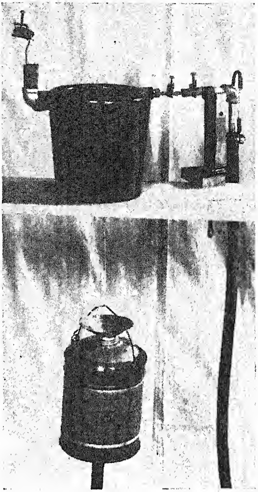

FIG. 1.—Double-walled pot with variable height reservoir. The photograph shows the air-trap, the water level gauge above the flexible hose, and the pinch clamp arrangement used for disconnecting the pot for weighing.

EXPERIMENTAL RESULTS

Knowing the weight of dry soil, the tare weight of the pot, and the moisture content of the soil corresponding to the gross weight of the pot at any one time, the average moisture content of the soil at any other gross weight can be calculated. In the first experiment the pots were filled with air-dried samples of surface soil that had been passed through a 2-mm sieve. A thin sheet metal lid was sealed in place with soft wax to prevent evaporation, but a small pin hole was made in the lid so that the soil air remained at atmospheric pressure.

The following soils which are typical of agricultural areas in Iowa were chosen for the experiments so as to give a range of texture: Wabash silty clay, Tama silt loam, Carrington silt loam, Dickinson loamy fine sand, and Buckner coarse sand.

At the start of the experiment the surface of the water in the reservoirs was raised to the level of the center of the pots and the curves in Fig. 2 show the variation of the gross pot weight plotted against a time scale with an arbitrarily chosen origin. The equilibrium steady

[4]Manufactured by the General Ceramics Company, New York, N. Y.

state values for the gross pot weight on each curve are serially numbered and the sharp breaks indicate a change in reservoir level.

The curves in Fig. 3 show the variation of the moisture content of the soil with the tension in the soil water expressed in centimeters of mercury as well as length of water column. The latter is given on the right margin of the figure and is simply the elevation of the soil above the water table. The serial numbers on the curves of Fig. 3 designate the corresponding equilibrium points on the respective curves of Fig. 2 and indicate the chronological sequence.

It is apparent from the curves that the dry soils used in the experiment wetted very readily when supplied with moisture at zero tension, approximate equilibrium moisture content in 6-inch pots being attained within a day or two. Subsequent moisture reductions in response to tension increases over a tension range from 0 to ½ atmosphere again took place rather rapidly and reached approximate equilibrium within 2 or 3 days. Moisture increases in response to tension reductions in the same tension range were somewhat slower, requiring at least 5 days and as in the case of the Carrington silt loam often as much as 20 days to attain equilibrium weight.[5]

A rather surprising result was obtained when a second pot of air-dry (4.3%) Wabash silty clay was allowed to wet up with the initial reservoir-setting at 10 feet. This curve is shown at the bottom of Fig. 2. It is seen that after 30 days equilibrium was not attained. The tensions for the equilibria 2, 3, 4, and 5 were, respectively, 0, 10, 7, and 3 feet of water.

In view of this slow wetting up of dry soil with water under tension, two more pots were filled with air-dry Clarion loam which were allowed to wet up at tensions of 5 feet and 13.8 feet of water. The data for this experiment are shown in Figs. 4 and 5.

It is significant to note from Fig. 4 that even though the maximum distance of travel of water through the soil was only 3 inches, at least 180 days were required to approach steady state. The temperature readings on a thermometer placed near the pot are graphically presented in Fig. 4. The pot weight increase that occurred in the time interval 200 to 225 days may be ascribed to the temperature drop that occurred at the close of the summer since it is known (7) that temperature change has an important influence on the relation between moisture content and tension in the soil water. It seems likely that even a longer time would have been required for the initial equilibrium under isothermal conditions.

DISCUSSION

Curves such as those shown in Fig. 3 are of considerable help in understanding drainage and moisture retention in field soils in the

[5]The approximately constant displacement of the second drying and wetting cycle toward higher moisture contents for the four soils shown in Fig. 3 was caused, in part, by a more complete saturation of the porous ceramic body of the pot during the course of the experiment. No adjustments in the calculations were made for this slow change in tare weight. This difficulty can be avoided by thoroughly saturating the irrigator pot at the beginning of an experiment.

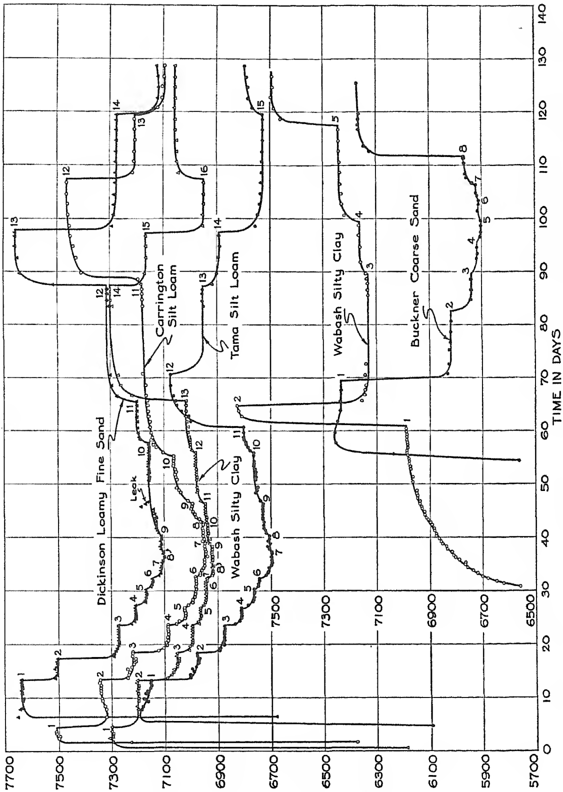

FIG. 2.—The variation of gross pot weight with time. The abrupt changes in the curves occurred just after changes in the elevation of the supply water reservoir.

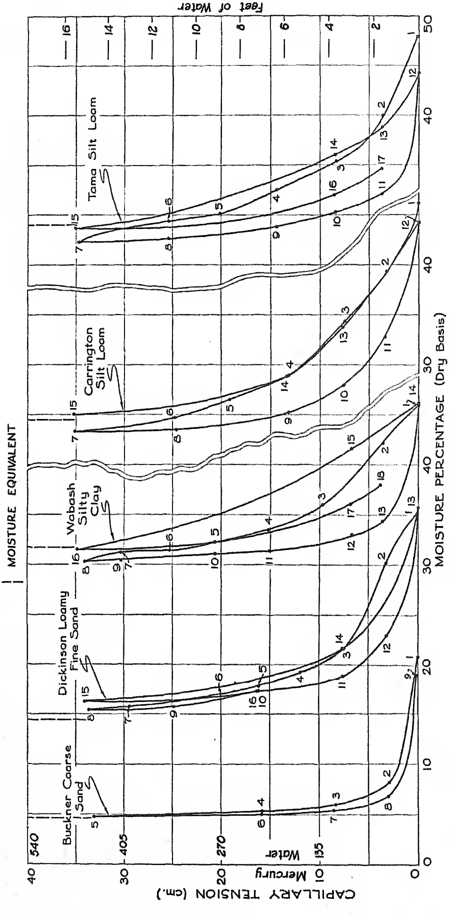

FIG. 3.—Sorption curves for five soils showing the hysteresis effect. The numbers correspond to the pot-weight equilibria shown in FIG. 2.

presence of shallow water tables. At a given height above the water table, after a soaking rain or irrigation, downward drainage cannot reduce the moisture content of a soil below the value indicated on the desorption curve (Fig. 3) at the tension corresponding to this height. At 4 feet above the water table, for example, minimum percentages attainable in the soils of the experiment by downward drainage would be Wabash 40, Tama 36, Carrington 33, Dickinson 21, and Buckner 6. Field measurements with tensiometers under corn (12) in Webster loam have shown that equilibrium tension distribution is attained and downward drainage to a 4-foot water table substantially ceases within a few hours after a heavy rain. Desorption curves help explain why it is that for maximum yields of many crops, field experience indicates that water tables must be lower in fine-textured soils than in coarse-textured soils.

The expression "entry value" is commonly used to refer to the pressure difference or suction required to make air penetrate into a saturated porous medium such as soil. For example, the porous inner wall of the pots used in this experiment had an entry value of 2 atmospheres. That is, when wet, the porous wall could withstand an air pressure difference of 30 pounds per square inch before air would leak through. During the process of draining soils, air enters and water is withdrawn first from the larger pores. A higher tension in the water is required to empty small pores and consequently at a given soil moisture tension fine-textured soils will retain more water than coarse-textured soils. Expressed in equivalent length of water column, the maximum tension that can be developed at any given point in field soil by downward drainage is equal to the elevation of the point above the water table. It often happens that soils in the field have sufficiently small pores and therefore sufficiently high entry values that they will remain saturated for appreciable distances above the water table.

It is apparent from the curves in Figs. 3 and 5 that changes in the equilibrium moisture content of the soil lag behind changes in the tension. The sorption and desorption curves resulting from cyclic changes in tension form loops instead of single curves. This lagging or hysteresis effect appears to provide an explanation for the fact that "auto-irrigators" do not provide an entirely successful means for controlling soil moisture in plant experiments (5). It is apparent that the sorption curves in Fig. 3 are much steeper than the desorption curves. Therefore, a small increase in moisture content during a wetting up process causes a large decrease in the driving force tending to move water from wet to dry soil. Thus, if moisture extraction by roots ever gets ahead of the rate at which the soil can supply moisture and a considerable drying out of the soil surrounding the roots results, then an auto-irrigator system goes over to the wetting up process like that illustrated in the beginning of the curves in Fig. 4 and the moisture content of the soil surrounding the roots will be only very slowly replenished unless supplied with water at considerably reduced tension. Apparently, in considering the rate of moisture movement in soils, one must distinguish carefully between wetting and drying processes and it is possible that current views on the

slowness of movement of water in soils are unduly influenced by the slowness of the "wetting up" process.

The curves in Fig. 4 taken for air-dry soil represent an extreme condition, of course, but field and laboratory experience combine to indicate that water under as low a tension as a sixth of an atmosphere can move into soils dried to the wilting point only with extreme slowness.

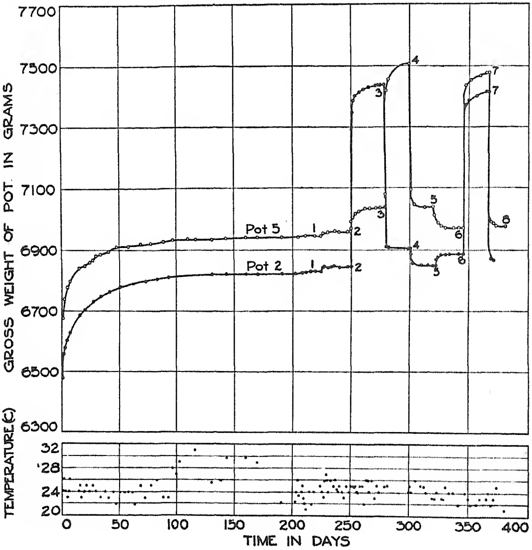

FIG. 4.—Curves showing the slowness with which water at the tensions 13.8 feet of water (pot 5) and 5 feet of water (pot 2) wets air-dry Clarion loam soil. Air temperature readings taken near the pots during the course of the experiment are shown at the bottom of the figure.

The data in Table 1 show an interesting relation between sorption data and the moisture equivalent. The numbers in the second column of the table were taken from the curves in Fig. 3 and show the moisture content of the various soils at the tensions shown in the first column of the table. The moisture contents obtained at tensions somewhat less than half an atmosphere correspond closely to the moisture equivalent values for these soils.

SUMMARY

Double-walled irrigator pots can be used for obtaining sorption and desorption curves for soils over the 1 atmosphere tension range. Since data can be obtained for either wetting or drying without

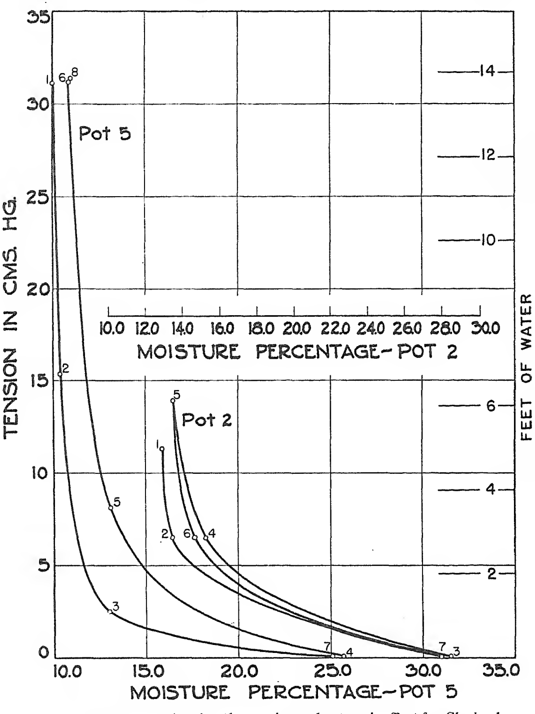

FIG. 5.—Sorption curves showing the maximum hysteresis effect for Clarion loam.

evaporation, air leaks, or time limitations, these pots are useful for studying hysteresis effects.

Data are presented which indicate that starting with wet soil in 6-inch irrigator pots, equilibrium moisture adjustments correspond-

ing to tension increases over the tension range from 0 to ½ atmosphere take place in 1 to 3 days, whereas equilibrium moisture adjustments corresponding to tension decreases required 4 to 20 days. Air-dry loam soil in 6-inch irrigation pots required as long as 180 days to wet up to equilibrium with water supplied at a tension as low as 11 cm of mercury (5 feet of water).

TABLE 1.—*Comparison of the moisture content of soil at the moisture equivalent and at approximately ½ atmosphere of soil moisture tension.*

Soil	Tension, cm mercury	Moisture % dry basis	Moisture equivalent*
Buckner coarse sand.........	33.1	4.7	4.6
Dickinson loamy fine sand....	34.0	16.3	14.4
Carrington silt loam.........	35.2	25.0	24.4
Tama silt loam..............	35.1	28.8	29.0
Wabash silty clay...........	34.8	31.5	31.7

*These moisture equivalent determinations were made with standard centrifuge equipment at the Intermountain Forest and Range Experiment Station, Ogden, Utah, through the courtesy of Dr. R. H. Walker.

Hysteresis between sorption and desorption curves helps to explain why dry soils are not readily rewetted by water which is under appreciable tension. It is this effect that accounts for the fact that auto-irrigators cannot be successfully used to control soil moisture for plant experiments over an appreciable range of moisture tension.

When considering moisture movements in soils, it appears necessary to distinguish between drying and wetting processes, the latter taking place at much slower rates under corresponding moisture conditions.

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COLD TOLERANCE IN FLAX[1]

A. C. Dillman[2]

THIS article reports the results of experiments carried on at Arlington Farm, Va., near Washington, D. C., during the three seasons of 1938–39 to 1940–41, inclusive. The purpose of the experiments was to determine (a) whether there is any significant difference in the cold tolerance of distinct varieties of flax, (b) to what extent the stage of growth determines the cold tolerance of flax plants, and (c) to develop strains having superior cold tolerance. The tests included 12 varieties, representing a wide range in agronomic types and including both seed and fiber varieties. The varieties were planted on three or more successive dates in order to have plants at different stages of development when freezing occurred. The plantings were made in the open, unprotected, except as explained later, and were subjected to the seasonal temperatures which might affect hardening of the plants previous to freezing temperatures. The results should be of interest to agronomists in states where flax is grown as a fall-sown crop.

Previous observations have shown that freezing injury to flax plants varies with the stage of growth. In the seedling or cotyledon stage, they may be damaged or killed by temperatures of 18° to 26° F, the extent of damage often depending on weather conditions immediately following the freezing. Such damage in the cotyledon stage sometimes occurs, although rarely, in the northern states where flax is grown as a spring-sown crop. In the blossom and green-boll stage injury may result from a light freeze of 30° F or slightly lower. At this stage freezing kills the flower buds and the immature seeds in the green bolls. Such damage occurs in the northern states when late-sown flax is not yet mature when frost occurs. Damage has been observed, also, in California and southern Texas, where flax, sown in early October, was in blossom in late February when a sudden freeze occurred. Because of frost hazard, mid-November seeding is recommended in those states. Flax sown in November will rarely reach the blossom stage until after danger of frost is past.

Flax in the vegetative stage of growth, that is, from the few-leaf stage to the flower-bud stage, appears to be most resistant to cold. In that stage commercial flax fields in California suffered little damage during two exceptionally cold periods in January 1937, when minimum temperatures of 14° to 17° F were recorded (2).[3] In some localities flax was injured, but on the whole, there was relatively little damage to the California crop that year.

Other pertinent observations have been reported by agronomists. A. C. Arny, Agronomist, University Farm, St. Paul, Minn., in a letter of November 5, 1923, wrote as follows:

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[1]Contribution from Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication April 1, 1941.

[2]Associate Agronomist.

[3]Figures in parenthesis refer to "Literature Cited", p. 799.

"This fall I seeded flax every other day beginning September 21, and had flax plants growing from germinating seeds up to 6 inches in height. Last Monday, Oct. 28, the thermometer registered 15° F. The ground was frozen 2 inches deep. Plants that were 3 to 6 inches high are uninjured, the stand being perfect. Well-germinated seed, but not yet emerged, also appears to be uninjured. Seedlings, in the 2-leaf stage, were injured most. The experiments show that flax can be seeded early, and in any stage of development it will stand a temperature of 23° or 24° F, and when 3 to 6 inches in height flax appears to be as hardy as other crops."

A strikingly different case, in which flax in a vigorous growing condition was killed, was reported by George T. Ratliffe, Superintendent of the San Antonio Field Station, San Antonio, Texas. Five varieties of flax, Linota, Redwing, Bison, Rio, and N.D. No. 114, seeded in drilled plots of 1/30 acre Dec. 29, 1931, were killed almost completely when "after a period of unseasonably warm weather the temperature suddenly dropped to a minimum of 14° F the night of February 7, followed by three nights when minima of 16°, 20°, and 22° F, respectively, were recorded. The plants were 6 inches high and in a succulent condition when the freezing occurred."

REVIEW OF LITERATURE

Davis (1) reported tests with seedling plants of fiber flaxes in which severe injury occurred at temperatures of 19° to 24°F. He stated, "While it is not safe to generalize on the relation between frost resistance and flax wilt from observations on only 15 kinds of flax, it is evident that, as a rule, the flaxes that are most resistant to frost are also strongly resistant to flax wilt." His varieties included only fiber flaxes and three strains of "short-fiber" flax, none of which is actually highly wilt resistant on badly infested soil.

Kremer (6) described winter flax, including the Roman Winter variety. The author quoted from a letter from Prof. E. Carbonne of Milan, Italy, in which it was stated that winter flax suffers when the temperature drops below 14°F.

Tobler (10) and Schilling (9) give a review of literature, quoting especially the paper by Davis.

Harrington (4) reported injury to flax in the 2-leaf stage by a minimum temperature of about 29°F. He stated that "The flax test showed a fairly distinct difference between Crown and Bison, the latter being more severely injured."

Ivanov (5) reported that the after-effect of frost in the seedling stage is reflected in retarded growth and later flowering, but also in a considerable increase of the length of the stems and a greater total dry weight.

Rzhavitin (8) determined by means of freezing chambers the relative cold resistance of 70 varieties of flax. Seedlings in the 6-leaf stage were somewhat hardened for 3 days at 32° to 40°F and then exposed to temperatures as low as 18°F. Most varieties were uninjured at 29°F, whereas all were killed or injured at 18°F. Contrary to the results of Ivanov (5), plants that survived showed weakened growth, delayed flowering, and reduced yield of stems and seeds. A few varieties appeared to have some degree of cold tolerance and made normal growth after exposure to freezing.

Kugler and Remussi (7) reported the injury to 319 varieties and strains of flax at the Pergamino Experimental Station, Argentina, after a freeze (17°F) when the

plants were 4 to 6 inches in height. Injury to certain of the varieties was as follows: Redwing, Bison, Bolley Golden, Ottawa 770B, Malabrigo, and Roman Winter, 5 to 10%; Concurrent, J.W.S., Rio, Bombay (Wis. 15), and *Linum crepitans* (dehiscent flax), 20 to 30%; Cirrus, 50%; Punjab (C. I. 20) and Indian, Type 12, 70 to 90% injury. The authors found no correlation between susceptibility to frost and wilt.

EXPERIMENTS

RESULTS IN 1938–39

In the autumn of 1938, 12 varieties of flax were planted in 16-foot rows at intervals of 2 weeks from September 12 to November 7, inclusive. Growing conditions were favorable during September and October and no killing occurred until late November, when minimum-temperatures of 22°, 12°, 13°, 16°, and 16° F occurred on five consecutive days from November 25 to 29. The survival of plants was estimated after 1 week and again about 3 weeks after the cold period. The data are presented in Table 1.

This cold period opened with sleet and wet snow, which covered the ground 2 to 5 inches deep over most of the field. In the three earliest seedings, the plants also were protected to some extent by tree leaves which had lodged among the taller plants. In the last two seedings, however, there was little protection either by leaves or snow.

Mean maximum and minimum temperatures by 5-day periods and certain daily minimum temperatures during the seasons of 1938–39 and 1940–41 are shown in Fig. 1.

At the beginning of the cold period on November 25, the plants of the fiber varieties, sown September 12, were 16 inches high; Redwing,

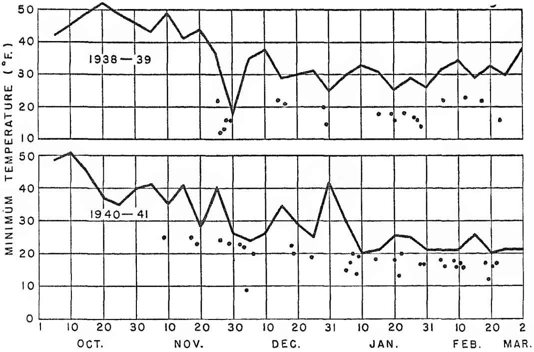

FIG. 1.—Mean minimum temperatures by 5-day periods at Arlington Farm, Va. Lowest daily temperatures are shown by dots.

Table 1.—Estimated survival of 12 varieties of flax sown on five dates in 1938 at Arlington, Va.

Variety	C. I. No.*	Percentage survival on Dec. 3 when sown						Percentage survival on Dec. 23 when sown					
		Sept. 12	Sept. 26	Oct. 10	Oct. 25	Nov. 7	Av.	Sept. 12	Sept. 26	Oct. 10	Oct. 25	Nov. 7	Av.
Redwing	320	20	50	70	70	60	54	0	15	20	60	5	20
Bison	389	40	80	80	70	60	66	0	20	20	60	5	21
Koto	842	40	70	70	70	60	62	10	10	10	50	5	17
Bolley Golden	644	80	90	90	80	90	86	80	90	80	80	20	70
Rigor	472	90	90	90	80	80	86	90	90	80	80	40	76
Rio	280	80	80	70	90	80	80	90	90	80	80	20	72
Roman Winter	470–1	90	100	90	90	80	90	100	100	90	80	10	76
Punjab	20	10	30	20	20	60	28	0	5	5	30	5	9
Indian, Type 12	—	10	15	20	20	20	17	0	5	5	10	5	5
Cirrus	881	10	10	30	20	60	26	0	0	0	10	5	3
Dorst I–13	799	15	10	15	50	60	30	0	0	0	20	5	5
J.W.S.	880	5	5	10	50	60	26	0	0	0	20	5	5
Average		41	53	55	59	64	54	31	35	32	48	11	31

*C. I. refers to accession number of the Division of Cereal Crops and Diseases.

Bison, and Koto, 12 inches; Bolley Golden, Rio, and Punjab, 9 inches; and Roman Winter about 5 inches. In the plot sown October 25 the plants were 2 to 3 inches high and had four to six leaves. In the plot sown November 7, the plants were well up but still in the cotyledon stage.

Roman Winter was the only variety to survive the winter. In the five consecutive seedings there were 10, 118, 4, 2, and 0 plants per row that matured. The older stems were killed back, but by February 20 a new growth of basal branches an inch or more in length had developed. The plants of the November 7 seeding that were in the cotyledon stage when the first severe freeze came perished during January. In the two earlier seedings, where the plants were protected somewhat by fallen tree leaves, the crown buds and basal branches on the partly hardy varieties Rio, Rigor, and Bolley Golden remained alive until mid-February but finally died. Minimum temperatures of 17°, 16°, and 14° F were recorded from January 26 to 28, and bare ground was frozen to a depth of 3 or 4 inches.

RESULTS IN 1939–40

In 1939, the same 12 varieties were planted in 4-foot rows in a bedding frame between two wings of a greenhouse at Arlington Farm on three dates, October 7, 14, and 21.

On December 12, a minimum of 24° F was recorded at Arlington Farm. There was no apparent injury to any variety. At that time the plants sown October 7 were 3 to 5 inches high, those sown October 14 were 2 to 3 inches, and those sown October 21 were just past the seedling stage, having only a few leaves above the cotyledons.

On January 2, a minimum temperature of 10° F occurred when the plants were fully exposed. In plants sown October 7, the stems and taller basal branches of all varieties except Roman Winter were killed, but the hardier varieties appeared to be alive at the crown. Greater injury occurred in the plants sown October 14 and 21. On January 5, eight representative plants from the first sowing of each variety were transplanted to a flat in the greenhouse for observation. All plants of Roman Winter, Rio, and Rigo recovered quickly and began normal growth, whereas most of the plants of Bison, Punjab, Indian Type 12, Cirrus, Dorst, and J.W.S. were dead (Fig. 2). Again the only variety that survived in the open was Roman Winter. In this variety, sown October 7, 90% of the plants survived and produced a normal crop of seed. In the two later plantings of October 14 and 21, Roman Winter was killed by the freeze (10° F) of January 2.

RESULTS IN 1940–41

In 1940, the 12 varieties were sown in 5-foot rows on three dates, September 24, October 1, and October 11; and on October 24, six varieties, two selections, and two hybrid strains in the F_4 generation also were sown. The plots were in the same location as in 1938–39.

No killing freeze occurred until December 4 when a temperature of 10° F was indicated by a minimum thermometer placed about an inch above the soil in the nursery. The minimum official temperature at Arlington Farm on that date was 9° F.

At the time of freezing, December 4, the height of the taller varieties in different seedings were about as follows: September 24, 6 to 8 inches; October 1, 4 to 6 inches; October 11, 3 inches; and October 24, 1 to 2 inches. Plants from the October 24 seeding had 4 to 10

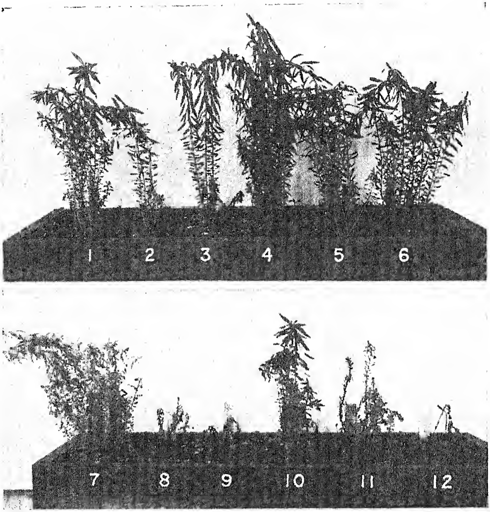

FIG. 2.—Survival and growth of flax plants sown October 7, 1939, and transplanted from outside bed January 5, 1939, after freezing injury (min. 10° F) January 1. The varieties are: 1, Redwing; 2, Bison; 3, Punjab; 4, Rigor; 5, Bolley Golden; 6, Rio; 7, Roman Winter; 8, Indian, Type 12; 9, Cirrus; 10, Koto; 11, Dorst I-13; and 12, J.W.S. Photographed February 21, 1940.

closely-spaced leaves but no basal branches. It is striking that the most injury occurred in the two earlier plantings and little or no injury occurred in the later planting. In the September 24 sowing, only Roman Winter was uninjured. The main stems of all other varieties, except a few plants of Rio, Rigor, and Bolley Golden, were frozen back to the crown. However, the crown buds and short basal branches were uninjured. The appearance of typical plants of certain varieties are shown in Fig. 3.

A cold period from January 4 to 7, following 2 weeks of fair weather, was accompanied by drying winds that whipped the flax plants badly,

especially where they were fully exposed, and all varieties suffered a considerable loss of plants. In the two earlier seedings, the plants

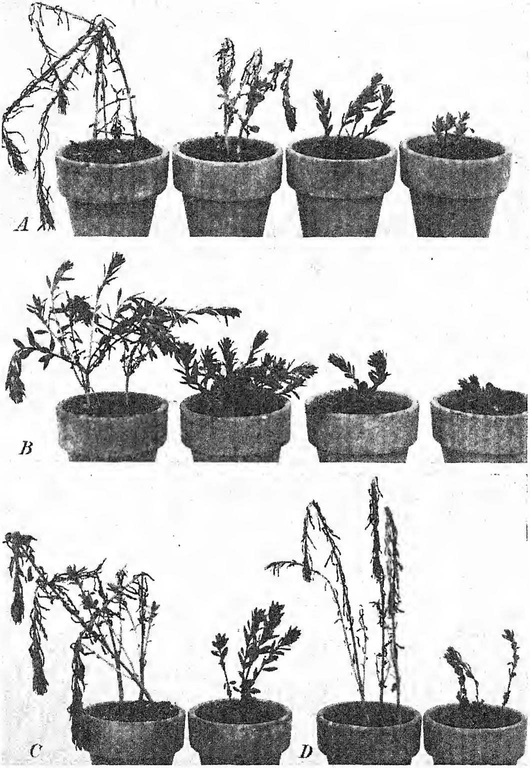

FIG. 3.—Appearance of certain varieties after freeze (9° F) December 4, 1940. A, Cirrus sown September 24 and October 1, 11, and 24, respectively; B, Roman Winter sown on the same dates; C, Bison sown September 24 and October 11; and D, Indian, Type 12, sown September 24 and October 11. Typical plants were set in 2-inch pots and photographed December 10, 1940.

were protected somewhat by weeds (henbit and chickweed) and fallen tree leaves. Minimum temperatures of 15°, 17°, 20°, and 14° F were recorded January 5 to 8, inclusive, by the official observer at Arlington Farm. The thermometer at the flax nursery recorded a low of 11° F during this period.

Prevailing temperatures during the 1940–41 growing season are shown in Fig. 1. Estimates of survival, recorded on December 13 and again on January 10, are shown in Table 2.

The cold tolerance of flax varies greatly, depending on the stage of growth, the degree of hardening previous to freezing temperatures, and also to weather conditions after freezing. Harrington (4) reported severe injury to seedling flax in early summer (June 4, 1935) from a light freeze (29° F), and Ratliffe reported complete killing of flax at San Antonio, Texas, when a sudden cold spell (14° F) occurred February 7, 1932, following warm weather. In contrast, the writer observed little or no injury to thoroughly-hardened seedling plants at 10° F (December 4, 1940), although the plants finally succumbed to frequent freezing at 14 ° to 20° F during January 1941.

RELATION OF GROWTH HABIT TO SURVIVAL

In habit of growth, the varieties showed very striking differences, especially in the earlier plantings. The fiber varieties Cirrus, Dorst, and J.W.S. had attained a height of 12 to 18 inches by mid-November of 1938. The plants were erect and had few or no basal branches. The Indian varieties Punjab and Type 12 were 8 to 10 inches in height with several basal branches. In contrast, plants of Roman Winter had many spreading or nearly decumbent basal branches, thus forming spreading bushy plants. The two Argentine types, Rio and Rigor, and also Bolley Golden were 6 to 10 inches in height, with usually four or more basal branches 1 to 4 inches in length. Redwing and Bison were intermediate in height with usually two basal branches. Thus it might be said that Roman Winter and the Argentine varieties had a more or less "winter habit" of growth, the plants being spreading or decumbent, whereas the fiber varieties and the seed flaxes, Redwing, Bison, and Koto grew erect as they do when spring sown. Representative plants of five varieties are shown in Fig. 4.

RELATION BETWEEN COLD TOLERANCE AND WILT RESISTANCE

Davis (1) stated that "most flaxes resistant to frost are also strongly resistant to wilt." This observation was based upon what appears to have been an accidental association between cold tolerance and wilt resistance among some of the few varieties that he tested. The relative degree of cold tolerance, wilt resistance, and rust reaction of 13 varieties grown in the present experiments, shown in Table 3, suggest that any relation between cold tolerance and disease resistance is purely incidental. The relation of cold tolerance to wilt resistance, including the data reported by Davis, is shown graphically in Fig. 5.

TABLE 2.—*Estimated survival of 12 varieties of flax sown on four dates in 1940 at Arlington, Va.*

Variety	C. I. No.	Percentage survival Dec. 13 when sown					Percentage survival Jan. 10 when sown				
		Sept. 24	Oct. 1	Oct. 11	Oct. 24	Av.*	Sept. 24	Oct. 1	Oct. 11	Oct. 24	Av.*
Redwing	320	10	10	95	—	38	10	10	40	—	20
Bison	389	10	10	90	95	37	10	10	10	0	10
Koto	842	20	30	95	95	48	20	30	10	5	20
Bolley Golden	644	20	20	100	—	47	20	20	40	—	27
Rigor	472	20	20	95	100	45	20	20	60	10	33
Rio	280	50	50	95	95	65	50	50	50	20	50
Roman Winter	470-1	90	90	100	100	93	90	90	70	40	83
Punjab	20	0	20	90	—	37	0	20	0	—	7
Indian, Type 12	—	10	10	80	—	33	10	10	0	—	7
Cirrus	881	5	10	95	70	37	5	10	0	0	5
Concurrent	801	10	10	95	—	38	10	10	15	—	12
J.W.S.	880	10	10	90	80	37	10	10	0	0	7
Average		21	24	94	91	46	21	24	24	10	23

*Not including October 24 planting.

TABLE 3.—*Relative cold tolerance, wilt resistance, and rust reaction of 13 varieties of flax.**

Variety	C. I. No.	Cold tolerance, %	Wilt resistance, %	Rust reaction
Redwing	320	23	75	Susceptible
Bison	389	16	96	Susceptible
Koto	842	16	95	Resistant†
Bolley Golden	644	50	65	Resistant†
Rigor	472	58	50	Immune
Rio	280	60	50	Immune
Roman Winter	470-1	78	40	Immune
Punjab	20	5	0	Resistant†
Indian, Type 12	—	5	20	Susceptible
Cirrus	881	3	20	Susceptible
Dorst 1-13	799	5	0	Susceptible
Concurrent	801	13	0	Susceptible
J.W.S.	880	5	10	Susceptible

*"Cold tolerance" is the average survival on December 20, 1938 (Table 1) and January 10, 1941 (Table 2). The wilt resistance is the average of two or more tests on wilt-infected soil at University Farm, St. Paul, Minn., and on plot 30 at the North Dakota Agricultural Experiment Station, Fargo, N. Dak. Rust reaction is based on the reaction to prevalent forms of rust as determined by Flor (3).

†Heterozygous, but chiefly immune.

BREEDING FOR COLD RESISTANCE

The obvious differences in the cold tolerance of different varieties of flax suggested the possibility of obtaining still greater cold resistance by hybridization or selection.

A few hardy plants that had survived temperatures of 12° to 16° F were transplanted to the greenhouse on January 12, 1939. A single plant in a row of Indian, Type 12, was uninjured, whereas all other plants in the row were dead. The progeny of this plant is listed in Table 4 as C. I. No. 1011. Two crosses, Rio × Roman Winter and Rigor × Roman Winter, were made in the greenhouse. The F_1 generation was grown at Bozeman, Mont., the F_2 generation at El Centro, Calif., and the F_3 generation again at Bozeman. Bulk seed of the F_3 plants was sown at Arlington Farm October 24, 1940. These

TABLE 4.—*Survival of certain varieties and hybrids at Arlington, Va., in January, 1941.*

Variety or hybrid	Percentage of survival, 1941		
	Jan. 18	Jan. 24	Jan. 26
Roman Winter	47	28	21
Rio	17	6	4
Rigor, C. I. 472-9	11	7	7
Rio × Roman Winter, F_4	29	16	14
Rigor × Roman Winter, F_4	25	16	11
C. I. 1011	77	54	49
Bison	0	0	0
Cirrus	0	0	0
J.W.S.	0	0	0
Koto, C. I. 842	0	0	0

hybrids and the selection C. I. 1011 have shown a remarkable degree of cold tolerance. The percentage of survival, based on counts of living and dead plants on January 18, 24, and 26, is shown in Table 4. Part of the killing appeared to have resulted from heaving, due to alternate freezing and thawing from January 5 to 15.

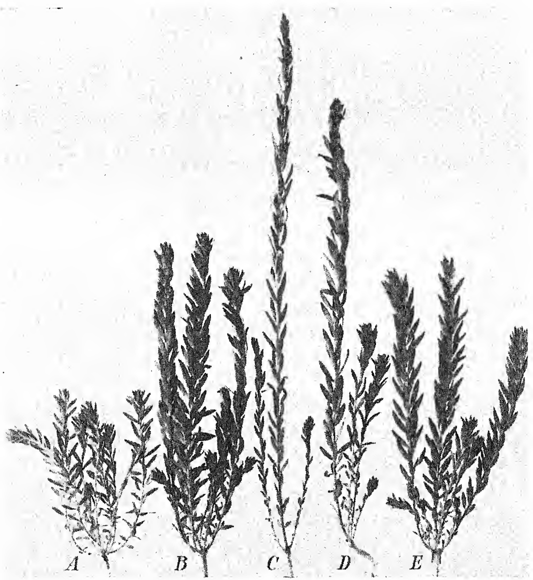

FIG. 4.—Representative plants (left to right) of A, Roman Winter; B, Punjab; C, Cirrus; D, Bison; and E, Rio, showing marked differences in height and in number of basal branches. The plants were spaced about 1½ inches apart in rows 1 foot apart. Sown September 12; photographed November 15, 1938.

SUMMARY

The cold tolerance of flax varieties sown in the fall at Arlington Farm, Va., was tested during three winters. The varieties Roman Winter, Rio, Rigor, and Bolley Golden were the most hardy. These hardier varieties have a branched spreading habit of growth when fall sown, whereas the less hardy varieties, including Redwing, Bison,

and fiber flaxes, grow erect with few or no basal branches as they do when spring sown.

In two of the three seasons covered by these experiments, plants 2 to 4 inches high at time of freezing were not greatly injured, whereas taller plants of the earlier plantings were frozen back to the crown buds. In 1940–41, the younger plants survived largely until mid-January, whereas the older plants perished earlier. In 1938–39, however, the larger plants, which were somewhat protected by fallen tree leaves, were still alive at the crown after the younger plants had died. In general, the younger tissues and the leaves of the terminal buds were more hardy than the older leaves on the stem.

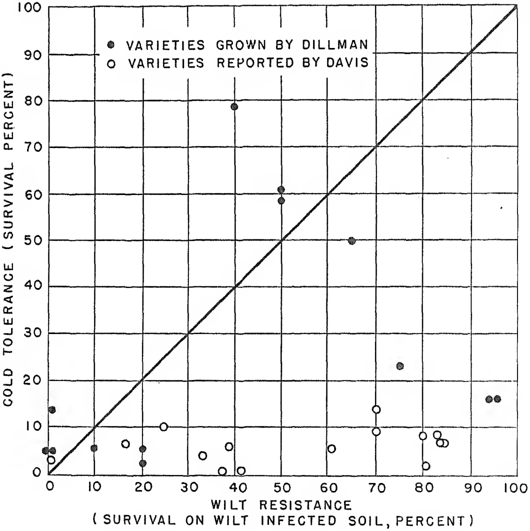

FIG. 5.—Relation of cold tolerance to wilt resistance.

A selection of a single surviving plant from a row of a tender variety proved to be remarkably cold resistant. Progenies of crosses of Roman Winter, a hardy variety, with Rio and Rigor contained plants in the F_4 generation that appeared to be as hardy as those of the Roman Winter parent.

There was no consistent relation between cold tolerance and wilt resistance.

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RETENTION BY SOILS OF THE NITROGEN OF SEVERAL AMIDES[1]

JOHN P. CONRAD[2]

IT was shown in a previous study (3)[3] that the nitrogen of formamide was strongly, though not completely, retained by the soil, while that of acetamide was but weakly retained. Differences in the adsorption by the soil of the chemicals themselves, as well as differences during the short period of percolation in the rates at which these chemicals split off ammonia, with the subsequent complete retention of this compound where formed in the soil, or a combination of these two factors, could adequately account for the results secured. Ammonia may have been formed from these compounds by either microbial or catalytic agencies or both. Experiments designed to evaluate these factors further are reported in this paper.

Among the naturally occurring amides, Sidgwick (11, p. 136) lists urea, the pyrimidines, the purines, asparagine, and glutamine, as well as several of the alkaloids. Peptides and proteins are considered as amino acids joined in chains by the peptide, an amide-like, linkage. Experiments with the more simple amides even though not of biological origin may throw some light on the behavior of the more complex ones in soils.

Using plant response as a criterion of nitrogen retention, preheating soils in a moistened condition to about 85° C was shown (2, 4) to destroy almost completely the ability of the soil to retain the nitrogen from a percolating solution of urea. Likewise, slowing the rate of percolation through unheated soil resulted in the increase of the nitrogen retained whether the percolation was carried out in soil abundantly treated with the antiseptic, toluene, or with no toluene at all. Subsequent chemical tests showed that preheated as well as untreated soil adsorbed small but approximately equal amounts of urea. Thermolabile catalysts, enzyme-like in their action, were similarly demonstrated in many heavily toluened soils (5). Tests similar to those used with urea, the diamide of carbonic acid, were employed in this study to determine whether or not the same factors were operative in the case of some of the other amides as well.

Formamide has been suggested (10) as a fertilizer or as an ingredient of mixed fertilizers. Plant studies (1, 10) indicate that it compares favorably with similar compounds as a source of nitrogen. Since it is liquid at ordinary temperatures, the greater ease of dissolving it in the irrigation water should give it some advantage over fertilizer salts in irrigated regions. Some knowledge applicable to practical situations might, therefore, be secured by including formamide with other amides in this study.

The following soils were used in this study: Nord loam, C-19, a subsoil (6 to 40 inches) lot from 4 miles northwest of Chico, California (12); Aiken loam, C-22, surface lot of virgin soil near Paradise, California (12); Yolo silt loam C-62, surface lot from the experimental plots near Davis, California (7); and Yolo fine sandy loam C-68, subsoil (12 to 24 inches) lot from the experimental plots near Davis, California (7).

[1]Contribution from the Division of Agronomy, University of California, Davis, Calif. The analyses reported herein were kindly carried out by Mr. J. A. Garibaldi, technician in the Division of Agronomy. Received for publication April 2, 1941.
[2]Associate Professor of Agronomy.
[3]Figures in parenthesis refer to "Literature Cited", p. 809.

GROWTH STUDIES

Sub-lots of the soils used were prepared for the growth studies as well as for the subsequent chemical studies by preheating to inactivate the enzyme-like catalysts of the soil. Dry soil was placed in crocks, moistened with distilled water, and, with the crocks covered, heated for at least 48 hours at approximately 85° C. Subsequently, the lots were dried, sieved and mixed for experimentation.

The technic of Conrad and Adams (6) was used to determine the retention of the nitrogen by the soil. Briefly, the method is as follows: Each of several 4-inch clay pots previously coated with asphaltum paint and prepared for the experiment by placing a square of waxed paper over the drainage hole to hold back the soil, was charged with 400 grams of dry soil deficient in nitrogen. Four pots were stacked to make a column and four columns were provided for each treatment investigated. Sufficient volume of solution to wet with slight excess the total amount of soil in the column was added in installments to the top pot of the column in question. The solution for each column receiving formamide contained approximately 10 m. at. N as this compound.[4]

The rate of percolation was varied. The columns percolated in 6 hours received the nutrient solution as rapidly as it would enter the top pot. For the 16-hour percolation, the solution was added in four portions, 4 hours apart. For the 42-hour percolation the four portions were added approximately 12 hours apart, but active percolation was assumed to be finished at the end of 42 hours.

The columns, after standing for a few hours following the end of percolation, were taken down and the pots cropped to milo. Tap water was used for irrigation. Each pot was nested into its drainage can, the drainage water being returned to the pot several times during the growth period. The final distribution of the nitrogen was judged by the increase in growth over that in the corresponding pots of the distilled water columns. The pretreatments, solutions, and the varying durations of percolations investigated are given in Table 1, together with the average yields of green milo secured.

Fig. 1 shows the growth of a representative replication of these cultures. These results are similar to those secured with urea. For comparable conditions with untreated soil the retention of the nitrogen of formamide was much greater than that of urea. Decreasing the rate of percolation decreased the amount of nitrogen getting through to the second pot of the column. Preheating the soil largely removed the capacity of the soil to retain the nitrogen of formamide. If the same principles apply as with urea, adsorption of formamide may be looked upon as weak but statistically significant, but the transformation of formamide to give ammonia was statistically significant and rapid.

CHEMICAL STUDIES

Studies with nitrogenous compounds which constitute nutrient sources may well include studies with plants for orientation purposes as in this study. The plants themselves or photographs of them serve to show the results graphically and to emphasize the importance of

[4]As used in this paper m. at. equals milligram atoms.

further study. If plants are materially affected, presumably the more accurate methods of analytical chemistry would show substantial differences.

TABLE 1.—*Retention of the nitrogen from solutions of formamide percolated at different rates through Yolo fine sandy loam variously treated as shown by the subsequent green growth of milo.*

Soil pretreatment and percolating solution	Duration of percolation, hours	Yield of green milo in grams per pot			
		1st*	2nd*	3rd*	4th*
None (normal soil)					
Distilled water		2.2	2.3	2.1	2.8
Formamide	6	21.9[1, 2]	7.2[2]	4.2	2.7
	16	22.1[2, 3]	4.0[4]	2.4	2.1
Preheated					
Distilled water		4.5	3.9	4.4	4.3
Formamide	42	19.5[2, 5]	17.9[2, 6]	15.1[2, 6]	11.6[2]

*Order in column.

Statistically different from the corresponding value:
[1]To the right (8, p. 112) $P<0.01$.
[2]For distilled water (8, p. 114) $P<0.01$.
[3]To the right (8, p. 112) P lies between 0.01 and 0.02.
[4]Immediately above (8, p. 114) P lies between 0.02 and 0.05.
[5]For the 3d pot of the same column (8, p. 112) $P<0.01$.
[6]For the 4th pot of the same column (8, p. 112) $P<0.01$.

ADSORPTION

The growth trials reported above suggest a weak but significant adsorption with preheated soil. The adsorption isotherms of several amides were determined by the usual laboratory method. Specifically, 100 grams of preheated soil were shaken for 2 hours with 50 cc of solution of various concentrations of the amide in question. Toluene in excess of saturation was present. The free solution was then filtered off and the concentration of water-soluble nitrogen determined by the usual Kjeldahl method. Similar tests were made with distilled water and the figures for adsorption corrected for the small but still detectable amounts of water-soluble nitrogen found in the extracts of the preheated soil. From these figures the amounts of nitrogen withdrawn from solution were calculated and the corresponding amounts adsorbed per kilogram of soil in equilibrium with the remaining concentrations computed.

In Fig. 2 are plotted logarithmically the amounts adsorbed per kilogram of soil against the equilibrium concentrations. In addition, the data previously published for urea, the diamide of carbonic acid, are also included for comparison. It will be observed that no very large differences occurred among the amides of the fatty acid series, although as the hydrocarbon chain attached to the carbamyl group ($CONH_2$) lengthened the adsorption became slightly less. The three points for propionamide did not lie close to a straight line, but did lie very close to the lines for the other amides. In the case of urea where NH_2 replaced the H of formamide the adsorption of nitrogen became

greater. The adsorption of the amide of aspartic acid, asparagine, was considcrably greater than that of urea.

PERCOLATION TESTS

As formamide was much more rapidly decomposed than the other amides, data secured with it will be reported after those of the other amides. One-quart percolators provided with the usual filter disks and filter paper were charged each with 1 kilogram of Yolo fine sandy loam with pretreatments as given in Table 2. Where the soil was to be percolated under toluene, this antiseptic was added to and mixed with the soil just before it was placed in the percolator.

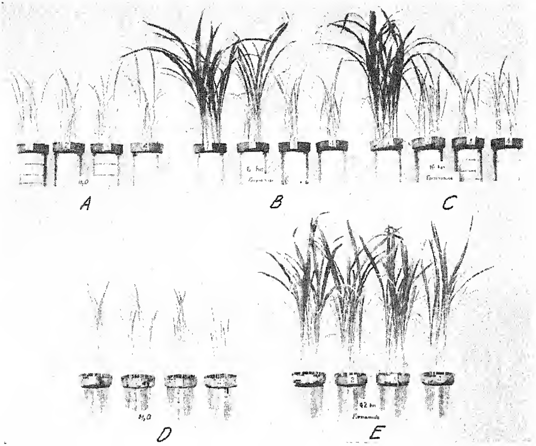

FIG. 1.—Effect of pretreatment and different rates of percolation on the retention of the nitrogen of formamide by Yolo fine sandy loam. Each group of four pots marked 1, 2, 3, and 4 were stacked in a column and subjected to a percolating solution. The soil used in columns A, B, and C was untreated, that in columns D and E was preheated. Columns A and D were percolated with distilled water, the others with formamide; B rapidly in 6 hours, C in 16 hours, and E in 42 hours.

Toluene in excess of saturation was added to each solution to be percolated through soil treated with toluene. Three hundred cc of the percolating solution were added to the soil-charged percolator, and at successive 12-hour intervals thereafter 100 cc of the same solution were added to each percolator. Each percolate was collected just before a new portion of the original solution was added at the

top of the percolator. The initial concentration of the solution and the residual concentrations in the percolates were determined by the usual Kjeldahl method. The percolations with normal soil without toluene showed the greatest reductions in concentration. The normal soil with toluene gave the next largest reductions with all amides except *l*-asparagine. The preheated soil with toluene showed after the first two percolates little retention of nitrogen.

TABLE 2.—*Reduction in concentration of the nitrogen of various amides in successive 100-cc percolates from kg portions of Yolo fine sandy loam as influenced by the antiseptic, toluene, and by preheating, results in milligram atoms N per liter.*

Percolating Solution	Soil pre-treatment	Anti-septic during perco-lations	Original nitrogen concen-tration	Reduction in concentration of nitrogen in successive 12-hour percolates					
				1	2	3	4	5	6
Acetamide.....	None	None	42.9	9.1	4.3	4.9	4.2	4.3	4.0
CH_3CONH_2	None	Toluene	42.9	5.1	3.1	3.6	3.3	2.1	2.0
	Preheated	Toluene	42.9	7.5	0.4	0.5	0.3	0.1	0.1
Propionamide	None	None	43.2	7.0	5.1	5.8	5.5	5.4	7.1
$C_2H_5CONH_2$	None	Toluene	43.2	6.0	2.4	2.7	1.8	2.1	1.2
	Preheated	Toluene	43.2	7.2	1.2	0.8	0.6	0.5	0.0
Butyramide	None	None	43.4	10.5	4.4	5.9	6.1	6.3	6.0
$C_3H_7CONH_2$	None	Toluene	43.4	7.1	1.5	1.9	2.0	1.9	2.0
	Preheated	Toluene	43.4	10.0	0.4	−0.4	0.5	0.4	−0.1
l-asparagine	None	None	75.4	73.2	72.4	62.0	44.4	26.8	18.6
$HOOC\ CHNH_2$-	None	Toluene	75.4	73.7	72.3	61.3	40.0	16.3	6.7
CH_2CONH_2	Preheated	Toluene	75.4	73.5	67.0	54.3	38.9	23.8	11.0

It is assumed that practically all of the reductions in the later percolates were caused by the retention of the NH_4 ions released from the amides as they percolate through the soil. This assumption is well substantiated by the work of Rehling and Taylor (10) who found that after 2 days of incubation, a large part of the added formamide nitrogen could be recovered in the ammonia form. If microorganisms are assumed to be inactivated by the toluene, the differences in retention of nitrogen between the normal soil and the preheated, both under toluene, may be attributed to thermolabile catalysis, presumably enzymatic. The differences between the reductions with unheated soil secured with and without toluene might be attributed to microorganisms, but injury by toluene to the catalytic activity in the toluened soil is not excluded as a possibility.

In the experiments with formamide, data secured from which are shown in Fig. 3, the percolators prepared as before were each charged with 400 grams of soil and 210 cc of formamide solution added to each one containing Aiken loam, 140 cc to each of the Nord loam, and 160 cc to each of the Yolo fine sandy loam to wet the soil. At successive 3-hour intervals thereafter 50 cc of the various solutions were added to their respective percolators, except as given below. In secur-

ing the data for the Yolo fine sandy loam curves for "Preheated (39.2) T" and "Predigested $HgCl_2$ (39.2) T", 75 cc portions were added successively to the respective percolators. In securing the data for the curve for the Yolo fine sandy loam "Normal (60) T" in Fig. 3, the charge of soil in the percolator was only 330 grams and successive percolates were 35 cc each.

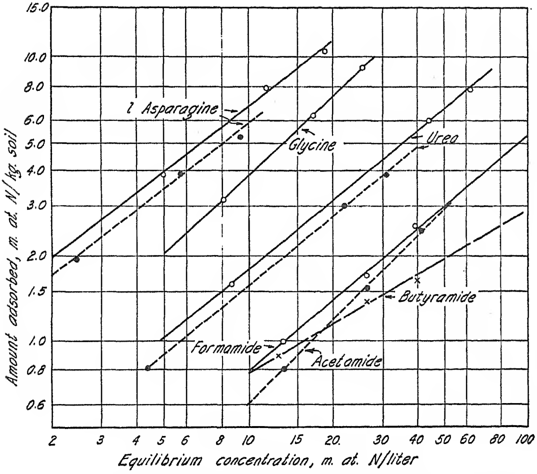

FIG. 2.—Adsorption of various amides by Yolo fine sandy loam. For those amides —urea and asparagine—which contain 2 atoms of nitrogen in the molecule, the dotted lines show adsorption on the basis of millimoles.

Preheating destroyed the ability of the Aiken and Nord soils to retain very much nitrogen after the first two or three percolates, while all of the unheated soils, even under various antiseptics, demonstrated their ability to retain nitrogen. There were only small losses in the ability of the soil to retain nitrogen where antiseptics were used on the Aiken loam. The various antiseptics used with the Nord loam resulted in the loss of about one-half of the ability to retain nitrogen from successive percolates. With the Yolo fine sandy loam some variations among the antiseptics likewise occurred.

Other pretreatments investigated included cropping for two years to several crops of oats (in the winter) and milo (in the summer) in pots in the greenhouse, and incubation in covered crocks in the same greenhouse for 16 months. No large variations because of either cropping or incubating this soil were evidenced by the data secured.

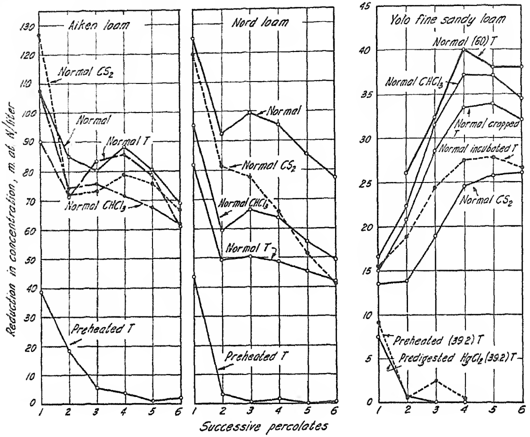

FIG. 3.—Reduction in the concentration of the nitrogen of formamide solutions percolated through 400 grams of different soils as affected by various antiseptics and pretreatments. "T" signifies the presence of toluene in excess of solution saturation during percolation. The original concentrations of percolating formamide solutions were 202.4 m. at. N per liter for the Aiken and Nord soils and 48.3 for Yolo soil, except as given in parenthesis on the curve in question.

TABLE 3.—*Reductions in the concentration of the nitrogen of formamide solutions percolated through 330-gram portions of Yolo silt loam as influenced by various antiseptics and pretreatments. Each portion of soil was wet initially with 135 cc of solution, results in milligram atoms N per liter.*

Soil pretreatment	Antiseptic during percolation	Original formamide concentration	Reduction in concentration of nitrogen in successive 35-cc percolates					
			1	2	3	4	5	6
None	None	196	118	98	114	128	128	123
None	$C_6H_5CH_3$	196	131	70	62	88	92	89
None	$CHCl_3$	196	112	66	76	94	102	100
None	CS_2	196	119	60	56	62	66	68
Preheated then cropped to:								
Sunflowers	$C_6H_5CH_3$	196	160	56	16	4	1.5	0.5
Soybeans	$C_6H_5CH_3$	196	82	22	19	22	10	0.5
Lupine	$C_6H_5CH_3$	196	78	31	14	7	2.5	1.0
Pumpkin	$C_6H_5CH_3$	196	106	32	5	1.0	1.0	1.0

As shown in Table 3, the use of various antiseptics resulted in loss of activity with Yolo silt loam with some differences showing up among the various antiseptics. In this experiment, 330 grams of soil were placed in each percolator as before and wet with 135 cc of solution.

Cropping of the preheated Yolo silt loam for two months resulted in increases in the soil's catalytic activities brought about by some of the crops, but these increases were by no means permanent, because as the percolations progressed the activities almost completely disappeared.

The same technic as used previously was employed in securing the data given in Table 4, except that the percolators were each charged with 330 grams of Yolo fine sandy loam. One hundred ten cc of solution were used to wet the charges of soil initially and successive portions of solution added were 35 cc each. All were percolated under toluene. In general, the time of contact of the solution with the soil is of greater importance than the concentration of the solution in determining the amounts of nitrogen removed from solution.

TABLE 4.—*Reductions in the concentrations of the nitrogen of formamide solutions percolated through 330-gram portions of Yolo fine sandy loam as influenced by different concentrations of formamide and by various time intervals between the additions of the successive portions of percolating solutions, results in milligram atoms N per liter.*

Time interval between percolates, hours	Original formamide concentration	Reduction in concentration of nitrogen in successive 35-cc percolates							
		1	2	3	4	5	6	7	8
¾	15	5.4	2.5	3.3	3.6	4.1	4.6	5.2	4.6
¾	60	26.5	—	9.0	7.5	7.5	7.5	8.5	8.0
3	60	—	26	34	40	38	38	34	34
3	127	56	53	48	50	44	43	40	39
12	127	60	94	104	104	102	99	92	84
12	488	120	116	150	140	126	104	90	68
48	488	354	448	470	458	442	428	436	430

DISCUSSION

The data presented in Fig. 1 and Table 1 strongly suggest that formamide was but weakly adsorbed by the preheated soil and inferentially also by the normal soil, and that during the most rapid percolation through normal soil, retention was caused by a breakdown of the formamide to yield NH_4-ions which, in turn, were strongly retained by the soil where split off. Slowing the rate of percolation and thereby increasing the duration of contact between the formamide solution and the soil removed more available nitrogen presumably as NH_4 from solution, suggesting again catalytic breakdown of the formamide. The chemical data substantiate and extend the suggestions arising from the growth studies.

At first the percolation methods used in the chemical studies might seem to be less exact than, let us say, displaced soil solutions or

equilibrium extracts. The method used had the following advantages, however: The relationship of soil to solution was very close to that existing under field conditions and the changes in concentrations of solutions were so great that the small errors of analysis were of little consequence.

With some charges of soil the solution percolated through rather quickly, while in others it took almost the whole time interval between adding successive portions of the original solution before dripping ceased. The amount added in successive portions was, in any case, but little more than one-half of the amount the soil held before dripping. After the first two or three percolates, the conditions for catalysis in any given percolator were approximately uniform for later portions of solutions added if the two following assumptions were true: (a) Any amount greater than that held by the soil when dripping ceased was too far away from catalytic surfaces (either above the level of the soil in the percolator or toward the outside of the films of soil moisture) to be materially affected by them, and (b) portions of solution added near the end of the test period percolated through the soil at the same rate as at the beginning. Though it is recognized that these assumptions were not fully realized in the procedures adopted, it is, however, considered that errors arising from these factors were relatively small.

Percolating a solution of constant concentration of a weakly adsorbed compound through a soil should result in the rapid attainment of an equilibrium between the adsorption surfaces of the soil and the solution such that after the first few percolates the solution would come through essentially unchanged. Such was the case with the preheated soils tested. If preheating the soils had simply reduced the adsorptive capacity, percolation with unheated soil would have shown higher initial amounts removed from the solution but with the removals nonetheless approaching a zero value rapidly. This type of behavior was not exhibited. The fairly constant reduction in concentration in successive percolates with a regular rate of addition of the percolating solution in the presence of excess toluene strongly suggests catalytic breakdown as an important factor.

MECHANISMS OF RETENTION

Though adsorption was weak with all amides investigated in this study, except *l*-asparagine, it was still one, though apparently not the most important, mechanism of retention.

The simplest mechanism for the liberation of NH_4 from these amides was by the hydrolysis of the carbamyl ($-CONH_2$) group to the ammonium salt of the corresponding organic acid with the subsequent retention of the NH_4 ions thus formed. Some minor differences in the rates of hydrolysis among the amides of acetic, propionic, and butyric acids were in evidence, but these were small compared with the great rapidity of decomposition of formamide. It would not be unreasonable to suppose that the three amides first mentioned had the same mechanism of liberating NH_4 ions and that that mechanism was hydrolysis. Sidgwick (11, p. 141), on the basis of non-

biological catalysts, states that formamide hydrolyzes more readily than other amides.

As is well known, asparaginase catalyzes the hydrolysis of asparagine to ammonia and aspartic acids. None of the other amides used in this study has any such well-recognized mechanism to account for its hydrolysis. Some biological systems have been reported, however, in which some of these amides have been broken down. Thus, Gorr and Wagner (9) reported that yeast cultures in the presence of a small concentration of phenol, as an antiseptic, all hydrolyzed asparagine. Only *Torula utilis*, however, hydrolyzed acetamide, propionamide, and lactamide, while neither this organism nor any of the other yeasts tested could hydrolyze formamide, oxamide, nor benzamide.

Splitting of the amides in the presence of antiseptics and the effects of different rates of percolation and concentrations on the retention of the nitrogen of formamide strongly suggest that catalytic activity to form ammonia was involved. The inactivation of this property both by preheating the soil and by pretreating it with $HgCl_2$ further suggests that the catalytic activity encountered may have been caused by enzymes.

SUMMARY

The ability of a soil rapidly to remove the nitrogen from a percolating solution of formamide was largely inactivated by preheating the soil. Slowing the rate of percolation resulted in the greater removal of nitrogen from solution. Plant response and chemical analysis were both employed in securing these results. Increasing the concentration of formamide in chemical studies, likewise resulted in increasing somewhat the amount of nitrogen removed from successive percolates. Several soils, both with and without various antiseptics, were able continuously to remove nitrogen from percolating solutions of formamide. Preheating these soils destroyed this ability.

Preheating removed the ability of the soil to reduce at a more or less constant rate the concentrations of acetamide, propionamide, and butyramide percolated at a constant rate through the soil. Percolation in the presence of excess toluene resulted in a substantial decrease in the ability of the normal soil to remove nitrogen from solutions of these amides.

Adsorption by preheated soil of formamide, acetamide, propionamide, and butyramide was definite but weak, while that of asparagine was somewhat greater.

The presence in the soil of thermolabile catalysts, presumably enzymes, which were able to catalyze the hydrolysis of these amides is strongly suggested by these data.

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APETALOUS AND PETALIFEROUS FLOWERS IN LESPEDEZA[1]

ROLAND MCKEE AND H. L. HYLAND[2]

IT has long been known that both apetalous and petaliferous flowers are found in Lespedeza, and the fact that pods from these two kinds of flowers differ from each other in shape has been incidentally mentioned by taxonomists. The extent and conditions of the occurrence of the two kinds of flowers and their significance, however, seems never to have received attention.

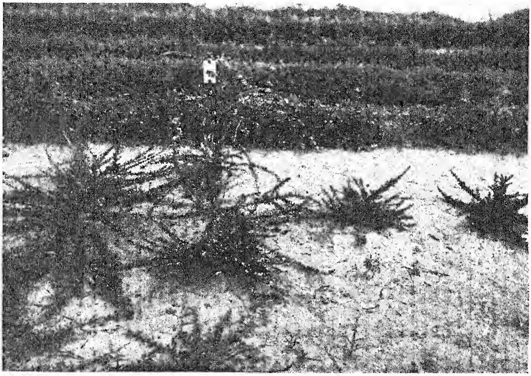

FIG. 1.—*L. latissima.* The two small individual plants on the right in the foreground are from seed from apetalous flowers. The two plants in the same row and to the left, one of which has a label, are from seed from petaliferous flowers.

In the past few years in connection with a general study of variation in Lespedeza, an attempt has been made to determine the significance of these two forms of flowers and the conditions under which they occur. General observation of a large number of species indicated that the occurrence of both petaliferous and apetalous flowers is common to most, if not all, species of the Eulespedeza and the Microlespedeza sections. It was further observed that the percentage of the two forms seems to vary with environmental conditions and possibly species. In order to ascertain more definite information on these points and to determine the significance, if any, of these variations, controlled observations were inaugurated at Arlington Experiment Farm, Virginia, where the studies are still in progress.

[1]Contribution from Division of Forage Crops and Diseases, U. S. Dept. of Agriculture, Washington, D. C. Received for publication April 2, 1941.

[2]Senior Agronomist and Associate Agronomist, respectively.

MATERIAL AND METHODS

In the five species *Lespedeza daurica* (Laxm.) Schindl., *L. inschanica* (Maxim) Schindl., *L. cystoides* (Pallas) Nakai, *L. cuneata* (Durn. de Cours.) G. Don, and *L. latissima* Nakai, both apetalous and petaliferous flowers were marked and seed in the pod obtained from the two kinds of flowers. A definite number of leaf axes were located on the flowering stem from which flowers were borne in sessile clusters or on compound pedicel-like flowering stalks of various lengths. In a few instances, both conditions occurred in the same axis. Three areas were marked on each plant studied. One area was left unmolested as a check. On another all the petaliferous

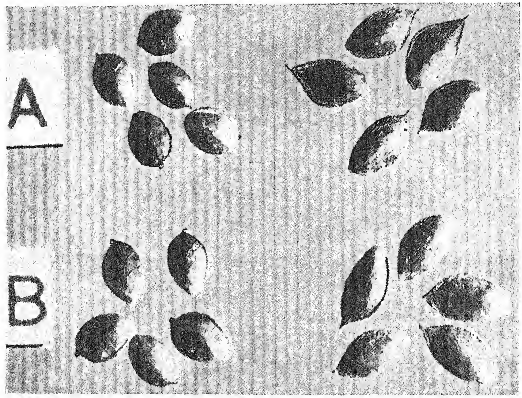

FIG. 2.—Pods of *L. cuneata*, A and B. Pods on the left are from apetalous flowers and those on the right from petaliferous flowers. A is strain 19284 and B strain 04730.

flowers were counted and removed and all such flowers counted only on the third stem. In making counts for the latter, it was necessary to avoid duplicate counting of the previous day's blooms. This was done by cutting off the tip of the floral standard immediately after counting. Daily counts on the stems under observation were made from the dates of first to last blooms and the seed in the pod was harvested a short time before fully mature to avoid loss due to shattering.

Seed from the two kinds of flowers, as indicated by shape of the pod, was selected from general lots of seed in the pod of *L. cuneata*, *L. inschanica*, *L. cystoides*, and *L. latissima*, and plants started in the greenhouse from this seed were later transferred to the field for further observation. Plants were also grown under greenhouse conditions for study of flowering under winter conditions of ordinary day length and varying day length as induced by artificial light.

DATA SECURED

Much of the information obtained is given in tabular form in Table 1 and the difference in the shape of the pod from the two kinds of flowers is shown in the accompanying illustrations.

In the species *L. cuneata*, *L. inschanica*, and *L. cystoides* seed from the two kinds of flowers, as indicated by the shape of pod, produced similar plants. In *L. latissima* the plants were quite dissimilar. This difference, however, seems to be confined to amount and manner of growth. The progeny of the seed from the petaliferous and apetalous flowers of *L. latissima* is shown in Fig. 1. The plants of *L. latissima* from seed from apetalous flowers are much smaller and more prostrate than the plants from seed from petaliferous flowers. Whether or not the larger plants represent hybrids with the factor for uprightness and large size of the pollen plant being dominant is not known, but the number of plants grown (52) and the definiteness of the differences would seem to eliminate the possibility of chance occurrence.

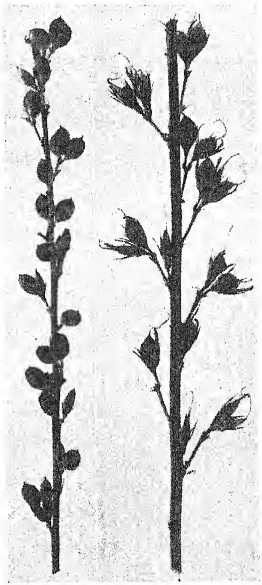

FIG. 3.—*L. cuneata*. The stem at the left shows seed in the pod from apetalous flowers, the one at the right seed in the pod from petaliferous flowers.

General observation has indicated that in some instances the number of petaliferous flowers vary from year to year and the data given in Table 1 seem to verify this observation. It will be noted that in 1939 *L. cuneata* had 75% of the seed from petaliferous flowers, while in 1940 but 31% of the seed was from petaliferous flowers. That the length of day or amount of light available during the flowering season may be a factor in determining the kind of flowers produced is indicated by the fact that in the greenhouse during the winter months under the shorter days only apetalous flowers are produced, while under longer days with artificial light some petaliferous flowers are formed. More information along this line is needed.

In all the species observed the pods from petaliferous flowers are larger and more acute than pods from apetalous flowers and have the

TABLE 1.—*Seed produced at Arlington, Va., from petaliferous and apetalous flowers under ordinary field conditions.*

Species	Seed produced when: Petaliferous flowers were removed in 1940	Apetalous flowers were removed in 1940	No flowers removed: Season of 1940			Season of 1939		
	No. of seed	No. of seed	No. of seed	Seed from petaliferous flowers, %	Seed from apetalous flowers, %	No. of seed	Seed from petaliferous flowers, %	Seed from apetalous flowers, %
L. cystoides	436	253	527	37	63	816	33	67
L. inschanica	132	137	239	52	48	—	—	—
L. daurica	147	230	419	71	29	—	—	—
L. latissima	8	5	19	42	58	124	48	52
L. cuneata	118	145	195	31	69	585	75	25

style persisting as a setaceous point. Without exception the pods from the apetalous flowers were comparatively blunt or rounded at the tip. In contrast to the pods from the petaliferous flowers the style on the pod from apetalous flowers remained as a short recurved hook. This is plainly shown in Figs. 2 and 3.

Of the five species in the Eulespedeza section for which data were secured, *L. daurica* produced most of its seed from petaliferous flowers. *L. inschanica* produced more seed from petaliferous than from apetalous flowers and in this respect was much like *L. daurica*. In *L. cystoides*, *L. cuneata*, and *L. latissima* most of the seed was produced from apetalous flowers. Some plants appeared to have many more petaliferous flowers that produced seed than others, but data for analyses of variance are not available.

DISCUSSION

The observations reported in this study were made from a limited number of plants for each species. Accurate evaluations of individual plant variations are not possible from data available, but the species variations noted are quite indicative. While these variations have some taxonomic significance, the main points of interest are the observations that petaliferous flowers are at times produced in abundance in all species and the indication that individual strains or plants differ in the percentage of petaliferous flowers produced. These observations then rather naturally lend to the speculation that these highly petaliferous flowering plants may, under favorable conditions, be subject to crossing and that this in turn may account for the wide variation in plants noted in some species. This phase of the subject needs further investigation and further information along this line should be helpful in any breeding program. So far as known no artificial crosses of Lespedeza have ever been accomplished, although attempts to cross species and strains have been made. Whether or not natural crosses exist, no one seems to know. That they do exist seems probable. The observations that have been made with reference to petaliferous flowers suggest that before making further attempts at crossing it is desirable to isolate individual plants and strains that are predominantly petaliferous and to ascertain, if possible, the environmental conditions conducive to the production of petaliferous flowers which presumably would in turn be most conducive to crossing. With proper plants and proper conditions it may be possible to effect artificial crossing in Lespedeza as a further aid in the improvement of varieties.

EFFECT OF ENSILING ON THE VIABILITY OF WEED SEEDS[1]

J. W. Zahnley and J. B. Fitch[2]

INTEREST in the problems pertaining to weed control has increased materially in recent years. The various means by which weeds are disseminated logically should be one of the first phases of the problem to be studied. Seed laws have aided in checking the spread of weeds in impure crop seed, but much less has been accomplished with reference to feeding stuffs. Means of devitalizing weed seed in feed for livestock have in the main been unsatisfactory. The use of the silo has raised a question as to the effect of the ensiling process on the viability of weed seeds produced with the silage crop. Investigations covering a period of seven years, 1927 to 1933, inclusive, are reported herein.

REVIEW OF LITERATURE

Several investigators have shown that the viability of the seed of certain species of weeds may be retained after passing through the digestive tract of farm animals. Atkeson, *et al.* (1),[3] Beach (2), Harmon and Keim (3), Korsmo (4), Milne (5), and Oswald (6) show that weeds can be spread in manure from animals fed on feed containing weed seeds. Relatively little work has been reported on the viability of seed after having passed through the silo. Premeisel (7) found that the viability of spores of corn smut was destroyed after several weeks in the silo.

Tildesley (8) found that the viability of 19 species of weed seeds was destroyed when the seeds remained in small experimental silos for 21 days and when the seeds were placed near the center of the silo. Seeds in the top layer of silage, however, retained a certain amount of their viability.

Woodward (9) found that the viability of the seed of most of 29 species of weeds and crops was destroyed when placed in silos with corn fodder, grass, and alfalfa at the time of filling. However, some germination was obtained from *Lespedeza sericea*, bindweed, and American dragonhead mint, while five species contained seed that was rated as "hard" or "sound" at the conclusion of the test.

MATERIALS AND METHOD

The silos were those used for storage of feed for the dairy herd of the Kansas Agricultural Experiment Station at Manhattan. They were of wood and concrete construction, 16 feet in diameter, of about 125 tons capacity, and filled mostly with sorghums but with corn in a few cases.

The selection of the species of weeds to be used in these tests was based upon two main considerations, *viz.*, the prevalence or the possible seriousness of the weed in Kansas, and the likelihood of the seed being found in silage under farm

[1]Contribution No. 320 of the Department of Agronomy and No. 136 of the Department of Dairy Husbandry, Kansas Agricultural Experiment Station, Manhattan, Kan. Received for publication April, 10, 1941.

[2]Associate Professor of Crops, Kansas Agricultural Experiment Station, and Chief, Division of Dairy Industry, University of Minnesota, former Head of Department of Dairy Husbandry, Kansas Agricultural Experiment Station, respectively. The germination tests were made in the Kansas State Seed Laboratory by Mrs. Anna Decker.

[3]Figures in parenthesis refer to "Literature Cited", p. 821.

conditions. This latter consideration involves the period of ripening of the seed, the habit of growth of the plant, and the effectiveness of weed control on the farm. The seed of each species was collected at the time silos were being filled throughout the community which was usually between September 20 and October 25. Seeds of the following weeds were used:

Rough pigweed (*Amaranthus retroflexus*)
Yellow foxtail (*Setaria glauca*)
Field bindweed (*Convolvulus arvensis*)
Giant ragweed (*Ambrosia trifida*)
Johnson grass (*Sorghum halepense*)
Annual morning glory (*Ipomoea purpurea*)
Smartweed (*Polygonum persicaria* and *pennsylvanicum*)
Barnyard grass (*Echinochloa crus-galli*)
Velvet leaf (*Abutilon theophrasti*)
Sunflower (*Helianthus annuus*)
Cocklebur (*Xanthium canadense*)
Lambsquarters (*Chenopodium album*) was substituted for rough pigweed in 1931

The seeds were collected from the field except in a few instances when this could not be done conveniently. In such cases seed was taken from supplies in the Seed Laboratory. Johnson grass is the only seed of which none was collected from the field throughout the experiment, and this was omitted from the silo in 1929 and 1930 on account of failure to obtain good seed.

One hundred seeds of each of 11 species were placed between two pieces of muslin about 18 inches square. The seed of each species was held in place and kept separate by sewing the two pieces of cloth together through the center then cross stitching every 3 inches to form compartments approximately 3 by 8 inches. Five such sets of samples were thus prepared. The cloths containing the seeds were placed in galvanized telescoping cans having a capacity of 25 to 30 pounds of silage and the silage was packed around them. These cans were imbedded in the silage at different depths in the silo, the first at the bottom, the second about one-fourth of the distance from the bottom to the top, the third about midway, and the fourth in the top 10 feet. The fifth set of seed used as a check was placed out of doors on the ground at the time the other four sets were placed in the silo and left exposed to conditions to which seed would normally be exposed if left in the field. This set was taken up in March of the following spring and tested for germination.

A sample of each lot of seed was stored in the Seed Laboratory and tested at the same time as those from the silo. Each sample removed from the silo before freezing weather was over was placed out of doors on the ground on the north side of a building where it would be exposed to freezing to simulate lying out in the manure as would occur if fed in silage and voided by the animal. Samples which were removed from the silo during spring and summer were placed in a refrigeration room of the Dairy Department and held at a temperature of approximately 40° to 44° F for 3 to 5 days before placing in the germinator. The samples were therefore not all subjected to the same temperature after removal from the silo, e.g., sets I and II, 1927, were exposed to –16° F, while the minimum to which set IV was exposed was 9° F. No record was made of temperatures within the silage, but the minimum was doubtless higher than that outside during the winter months.

RESULTS

Samples were removed from the silo as they were encountered while removing silage for the regular feeding of the dairy herd. When removed the cloths containing the weed seed had a normal silage odor and were wet with the juice of the silage. So far as could be detected from the odor, moisture content, and general appearance, the forage material within the loosely covered cans had formed the same quality of silage as that outside.

Table 1 shows the date on which the seed was placed in the silo, the number of days each lot remained in the silo, the number of the 11 species tested of which some seeds germinated after removal from the silos, and the total number of seeds of each set that germinated. The shortest time that any set remained in the silo was 33 days for set IV in the fall of 1927. Set II of the 1928 crop remained in the silo

TABLE 1.—*Number of species and total number of seeds that germinated after storage in silage for different length periods.**

Year	Date seed was placed in silo	Number of days in the silo				Number of species that germinated				Total number of seeds that germinated			
		Set I	Set II	Set III	Set IV	Set I	Set II	Set III	Set IV	Set I	Set II	Set III	Set IV
1926	Oct. 22	180	169	152	106	0	0	1	0	0	0	6	0
1927	Oct. 5	124	92	62	33	3	3	3	3	157	134	149	130
1928	Oct. 1	Lost	1,636	1,102	346	Lost	3	3	2	Lost	28	43	41
1929	Oct. 1	—	—	—	44	0	0	0	0	0	0	0	0
1930	Oct. 9	289	281	200	156	3	3	3	3	95	91	85	115
1931	Oct. 3	555	541	291	189	4	2	3	3	74	108	55	10
1932	Oct. 10	197	166	140	73	1	3	3	3	2	123	123	138

*Each set consisted of 1,100 seeds comprising 100 seeds of each of 11 species.

TABLE 2.—*Effect of the ensiling process and of freezing upon the germination of weed seeds, average 7-year period, 1927–33.*

Kind of seed	Germination percentage following different treatments		
	Stored in laboratory	Placed outside on ground	Placed in silo with silage
Pigweed	13	20	0
Yellow foxtail	34.5	47	0
Field bindweed	10	27	16
Giant ragweed	2	4	0.1
Johnson grass	37	32	0
Morning glory	82.5	15	8
Smartweed	0	10	0
Barnyard grass	1	10	0.3
Velvet leaf	26	31	38.5
Sunflower	0	14	0
Cocklebur	4	22	0

from October 1, 1928, to March 25, 1933, a period of 1,636 days. In each of these cases some of the seeds germinated.

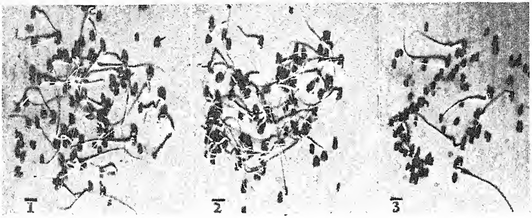

FIG. 1.—Field bindweed (*Convolvulus arvensis*). *Left*, stored in the silo with sorgo silage October 1 to December 22, 1932, then stored outside until April 10, 1933. *Center*, stored outside from November 15, 1932, to April 10, 1933. *Right*, stored in seed laboratory October 1, 1932, to April 10, 1933. Photographed April 15, 1933, after 5 days in the germinator.

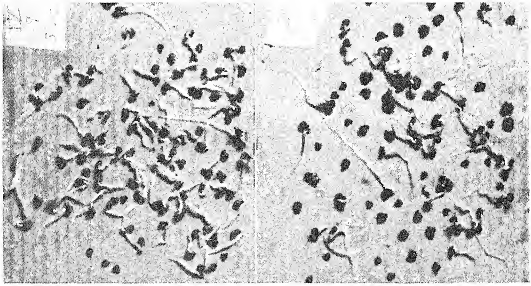

FIG. 2.—Velvet leaf (*Abutilon theophrasti*). *Left*, stored in silo October 1928, to January 1929, and left outside exposed to freezing until March, germination 85.5%. *Right*, not placed in silo but stored outside from October to March, germination 40%.

There seemed to be no consistent relationship between length of time the seed remained in the silo and its ability to germinate when removed. In the case of the 1929 crop, none of the 11 species germinated after remaining in the silo 44 days or longer. On the other hand, 28 of the 1,100 seeds in set II of the 1928 crop germinated after remaining in the silo for over four and a half years.

In Table 2 the average percentage germination is recorded for the seed which was stored in the laboratory, that which was placed out of

TABLE 3.—*Effect of ensiling and of freezing upon the germination of weed seeds, 1927–33.*

Kind of seed	Treatment and number of seeds in each sample of 100 that germinated																			
	Stored in laboratory and out of doors													Stored in silage—ave.—four sets*						
	1927		1928	1929		1930		1931		1932		1933		1927 †	1928	1929	1930	1931 ‡	1932	1933
	Dry	Frozen	Frozen only	Dry	Frozen	Dry	Frozen	Dry	Frozen	Dry	Frozen	Dry	Frozen							
Pigweed‡	8	18	22	29	55	0	0	0	8	1	0	39	37	0	0	0	0	0	0	0
Yellow foxtail	0	0	25	14	0	43	0	51	84	22	10	77	69	0	0	0	0	0	0	0
Field bindweed	12	24	50	11	29	16	0	7	33	2	4	11	52	1.5	37	4	0	29	13	25
Giant ragweed	0	4	0	0	4	10	0	0	0	0	4	0	15	0	0	0	0	0	1	0
Johnson grass§	28	42	2	30	16	**	**	49	51	26	31	52	51	0	0	0	**	**	0	0
Morning glory	94	0	2	87	1	90	0	39	24	96	24	89	46	0	20	3	0	6	1	27
Smartweed	0	40	4	0	5	0	0	0	2	0	0	0	19	0	0	0	0	0	0	0
Barnyard grass	0	16	51	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0
Velvet leaf	1	36	40	46	33	10	0	22	66	24	13	45	32	0	85.5	31	0	62	46	45
Sunflower	0	18	30	0	2	0	0	0	0	0	0	0	46	0	0	0	0	0	0	0
Cocklebur	0	56	30	3	30	3	3	0	10	10	16	6	9	0	0	0	0	0	0	0

*Three sets recovered in 1929.
†Not frozen.
‡Lambsquarters substituted for rough pigweed in 1931 crop.
§Johnson grass seed not used with other samples of 1929 crop, on account of inability to obtain good seed.
**Johnson grass was not put in the silo in 1930.

doors an exposed to natural weather conditions, and that which passed through the silos. The viability of field bindweed seed after these three kinds of treatment is shown in Fig. 1. Nine of the 11 species gave a higher germination when stored outside on the ground than when kept in the laboratory. Two species, morning glory and Johnson grass, gave higher average germination when stored in the laboratory. As a general rule a much lower average was obtained from the seeds that were placed in the silo. Velvet leaf in 1928 was a notable exception, giving a higher germination after going through the ensiling process (Fig. 2). Field bindweed gave an average germination for the 7-year period of 16% after going through the silo. The average for velvet leaf and morning glory for the same period was 38.5 and 8%, respectively. Giant ragweed and barnyard grass germinated only 1 year of the 7 while pigweed, yellow foxtail, Johnson grass, smartweed, sunflower, and cocklebur showed no viability after going through the silo.

The results of germination tests of each of the 11 species under the different methods of treatment for each year of the 7-year period are given in Table 3.

SUMMARY AND CONCLUSIONS

1. Five sets of 100 seeds each of 11 species of weeds were used in these tests each year for a period of 7 years.

2. The seeds were placed in the silage in different silos and at different locations in the silos where they remained for periods ranging from 33 to 1,636 days.

3. Five of the 11 species used show some germination after storage in the silo. Field bindweed germinated in 6 of the 7, years, while annual morning glory and velvet leaf germinated in 5 of the years.

4. Field bindweed gave an average germination of 16% after passing through the silo compared with 27% when stored outside exposed to the weather. Velvet leaf gave higher germination after storage in the silo than when stored outside.

5. Twenty-eight seeds comprising three different species germinated after approximately 4½ years in the silo.

6. The viability of rough pigweed, yellow foxtail, Johnson grass, smartweed, sunflower, and cocklebur was apparently destroyed in the silo. The seed of field bindweed, velvet leaf, morning glory, giant ragweed, and barnyard grass, however, seemed able to resist the effect of ensiling.

7. The danger of spreading certain species of weeds by means of corn and sorghum silage crops is reduced but not eliminated by ensiling the crop.

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EXPLORATORY TESTS OF SUBSOIL TREATMENTS INDUCING DEEPER ROOTING OF POTATOES ON WOOSTER SILT LOAM[1]

JOHN BUSHNELL[2]

ON silt loam and sandy loam soils in Ohio, potato roots are found largely in the plowed layer, with only a few small roots extending into the subsurface soil. Similar shallow rooting was reported by Farris (3)[3] in New Jersey and by Beckwith (1) in central New York. In contrast, Weaver (6) in Nebraska found roots 4 feet deep, Ten Eyck (5) reported the same in North Dakota, and the writer (2) found numerous roots at a depth of 30 inches in muck soil in Ohio. The conclusion to be drawn is that potatoes normally root to a depth of 3 or 4 feet unless prevented by some unfavorable condition of the soil.

The aim of the work reported here was to determine what treatments would induce abundant rooting of potatoes in the subsurface layer of Wooster silt loam, and if this would be accompanied by higher yields of tubers.

PROCEDURE

The soil used had been plowed 10 inches deep for several years. Below the plowed layer the soil was well oxidized, brownish, silt loam to a depth of 24 to 30 inches. There was no distinct hard pan and the B horizon had only a slight accumulation of clay. To a depth of 28 inches the pH was 4.6 to 5.0. Rapid soil tests by Morgan's method (4) in the spring of 1936 and again in 1938 showed no nitrates or ammonia and very little available phosphorus or calcium.

An initial test in 1931 of loosening the subsoil with a subsoiling implement resulted in no appreciable increase in root development nor in yield of tubers. On the other hand, mixing manure with the subsurface soil resulted in abundant roots and an increase in yield. Thus it appeared that the nutrients supplied by the manure induced the root development, and the following tests were planned to determine whether similar root growth could be induced by chemical nutrients.

To test a considerable number of chemicals in an exploratory way, a procedure was adopted of boring a row of holes with a post hole auger, mixing the materials with the subsoil,[4] and planting potatoes directly above. The holes were about 8 inches in diameter and extended 18 inches below the plowed soil. The volume of treated soil in each hole was about 15 liters, the dry weight about 22 kilograms. To avoid contamination with surface soil, it was first shovelled aside and replaced after the holes were prepared. To insure good mixing of the materials, the subsoil was screened into a tub, the materials added, and the mixture poured from one tub to another, then replaced with light tamping. For checks the soil from every fifth hole was similarly handled but nothing added. Russet Rural potatoes were planted immediately after the row of treatments was completed.

[1]Contribution from the Department of Horticulture, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication April 12, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 827.

[4]Hereafter, in referring to the treated soil, the term "subsoil" is used instead of the longer "subsurface soil."

About 100 cores of subsoil were thus prepared in each of four seasons, from 1936 to 1939, inclusive. All of the materials listed in Table 1 were not tested every season, but when included were applied at three or four rates, without replication. The initial amounts applied were such as to carry ¼, ½, 1, and 2 mols of either phosphorus, nitrogen, or calcium. If the larger quantities proved toxic, as indicated by a complete absence of roots, a range of smaller amounts was tested the following season.

At the close of each season, the surface soil was again shoveled aside and a ditch dug along the row to expose one side of each treated core of soil (Fig. 1). The roots in the interior of the cores were then exposed by gently picking away part of the soil from top to bottom (Fig. 2). An estimate was then made of the quantity of roots in comparison with the checks.

RESULTS

It was evident each season that the relative abundance of roots fell into three distinct classes, *viz.*, first, roots at least five times as numerous as in the checks; second, roots not distinctly more numerous than in the checks; and third, roots absent. The absence of roots was taken as an indication of toxicity except where the material had caused the soil to become wet and sticky, a condition presumably unfavorable for root growth. With some of the materials the amounts applied extended from ineffective amounts through a range which distinctly increased the roots to toxic concentrations.

EFFECT OF SUBSOIL TREATMENTS ON ROOT DEVELOPMENT

Among the treatments giving abundant roots there were discernible differences in the quantity of rows and these were recorded, but in comparing the data of the four seasons the differences were not sufficiently consistent to be significant. On the other hand, all of the materials inducing root development distinctly superior to that of the checks in one season proved likewise superior to the checks in the other seasons if applied at the same rate. Hence, the effective materials are simply classed as one group in Table 1.

All of the phosphates tested, except the sodium phosphates, increased the quantity of roots in the treated subsoil. Likewise, the ammonium salts, urea, and cyanamid were effective. The ineffectiveness of the sodium salts was probably due to a sticky soil structure they produced. The nitrate salts were toxic at all except the smallest applications tested, but in no instance, except with ammonium nitrate, did the light applications induce abundant roots.

The obvious conclusion is that suitable carriers of either phosphorus or nitrogen increased the quantity of roots in this subsoil, and that it was not necessary to add both of these nutrients.

EFFECT OF SUBSOIL TREATMENTS ON YIELD OF TUBERS

To determine the effect on yield of tubers, the materials listed in Table 2 were mixed with the subsoil under 50-foot rows. Trenches about 12 inches wide and extending 18 inches below the plowed soil

were dug with a shovel. The materials were mixed with the soil as it was shoveled back, except in the one case where surface soil entirely replaced the subsoil. After the trenches were refilled and the surface soil replaced, Russet Rural potatoes were planted directly above and fertilized along the rows with 4–8–8 at the rate of 1,000 pounds per acre. The trenches of treated subsoil were 64 inches apart, leaving room for a guard row of potatoes between.

TABLE 1.—*Materials mixed with cores of subsoil grouped according to whether they did or did not distinctly increase the quantity of roots in the treated soil.*

Chemical or fertilizer applied, formula or composition	Amounts applied		Years tested
	Range tested, grams	Most effective amount, grams	
Materials Inducing Roots at Least 5 Times as Numerous as in the Checks			
Calcium phosphate, $Ca_3(PO_4)_2$	39 to 310	39 to 310	4
Calcium Phosphate, $Ca\ HPO_4.2H_2O$	43 to 344	43 to 84	4
Calcium phosphate, $CaH_4(PO_4)_2.H_2O$	32 to 128	64	3
Ammonium phosphate, $(NH_4)_2HPO_4$	33 to 132	33 to 66	2
Ammonium phosphate, $NH_4H_2PO_4$	29 to 115	58	4
Magnesium phosphate $Mg_3(PO_4)_2.8H_2O$	42 to 168	42 to 168	2
Potassium phosphate, KH_2PO_4	34 to 136	68	3
Superphosphate, 20%	44 to 358	89 to 358	4
"Ammo-phos", 11–48–0	18 to 292	37	3
Ammonium nitrate, NH_4NO_3	5 to 160	20	3
Ammonium sulfate, $(NH_4)_2SO_4$	8 to 132	8 to 16	3
Urea, $(NH_2)_2CO$	4 to 120	30	2
Cyanamid (fertilizer) 22% N	16 to 127	16	2
Materials not Distinctly Increasing the Quantity of Roots			
Calcium nitrate, $Ca(NO_3)_2$	41 to 164	—	3
Magnesium nitrate, $Mg(NO_3)_2.6H_2O$	64 to 128	—	1
Potassium nitrate, KNO_3	14 to 202	—	4
Sodium nitrate, $NaNO_3$	43 to 170	—	3
Calcium carbonate, $CaCO_3$	25 to 200	—	4
Calcium sulfate, $CaSO_4$	43 to 172	—	1
Sodium phosphate, $NaH_2PO_4.H_2O$	35 to 138	—	2
Sodium phosphate, $Na_2HPO_4.12H_2O$	45 to 179	—	1

Without further treatment of the subsoil, potatoes were grown for four seasons. Immediately after each harvest, one end of each treated row of subsoil was examined to estimate the number of roots, and the soil under four guard rows similarly examined.

As indicated in Table 2, roots were found more numerous in the phosphated subsoil than in either the loosened or undisturbed subsoil. In the phosphated rows, however, the roots were only about half as numerous as in the phosphated cores shown in Figs. 1 and 2. The only treatments producing a truly abundant root development were the Ammo-phos application in the first year and the manure in the second year.

TABLE 2.—*Abundance of roots and yield of No. 1 tubers in bushels per acre from subsoil treatments directly under potato rows, average of duplicate 50-foot rows.*

Treatment*	1936		1937		1938		1939	
	Abundance of roots†	Yield of tubers, bu.	Abundance of roots†	Yield of tubers, bu.	Abundance of roots†	Yield of tubers, bu.	Abundance of roots†	Yield of tubers, bu.
Nothing, subsoil undisturbed‡	+	271.0	+	196.0	+	155.6	+	196.9
Nothing, subsoil loosened	+	280.8	+	197.1	+	152.8	+	198.0
Lime, hydrated, 80 lbs.	+	295.5	+	190.2	+	153.6	+	189.8
Superphosphate, 20% 20 lbs.	++	291.1	++	187.6	++	161.4	++	200.8
Lime, 80 lbs., superphos., 20 lbs.	++	296.6	++	191.0	++	160.6	++	194.2
Ammo-phos (11–48–0), 8.4 lbs.	+++	328.2	++	220.9	++	147.2	++	190.5
Manure, 20 cu. ft.	—§	232.3	+++	231.7	++	150.0	++	214.5
Surface soil, 80 cu. ft.	++	295.5	++	232.2	++	153.6	++	200.6
Difference required to give odds of significance of 19:1**		18.3		21.0		28.1		23.5

*Mixed with subsoil in 1936; about 80 cubic feet treated under each 50-foot row.
† + indicates roots approximately as numerous as in the undisturbed subsoil; ++ indicates roots about 5 times as numerous; +++ indicates roots at least 10 times as numerous as in the undisturbed subsoil.
‡Average of the guard rows between the treated rows.
§No roots found in subsoil where fresh manure was applied in the spring.
**Estimated from the variation in the yield of the guard rows.

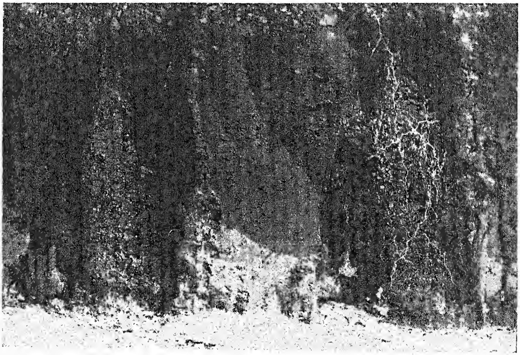

FIG. 1.—Potato roots at interface between treated cores and the undisturbed subsoil, 1936. Core at left mixed with superphosphate; nothing added to core at right.

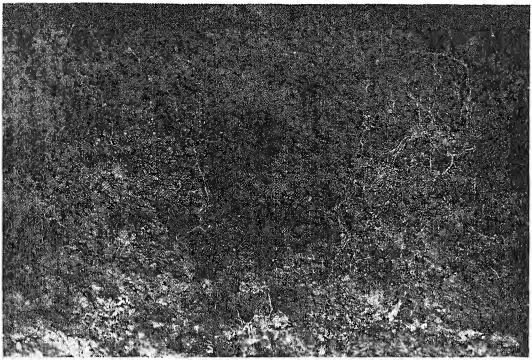

FIG. 2.—Roots in the interior of treated cores of subsoil, 1937. Core at left with monoammonium phosphate; nothing added to core at right.

Except for the large increase in yield from Ammo-phos the first year, most of the increases were not large enough to be distinctly significant. The effect of the Ammo-phos was probably due to its nitrogen, for the plants were noticeably larger in 1936 but not in the following seasons.

The conclusion from this small test is that phosphating or liming this subsoil did not consistently increase the yield of potatoes, even though there was an increase in the amount of roots in the phosphated soil. As a tentative corallary, it appears that shallow rooting is not an important limiting factor in yield of potatoes on this type of soil.

SUMMARY

On Wooster silt loam with a well-oxidized, silt loam subsurface soil, the addition of certain phosphorus and nitrogen chemicals to the subsurface soil distinctly increased the quantity of potato roots in the treated soil. Thus, the normal shallow-rooting on this soil is attributed to the lack of available nitrogen and phosphorus in the subsurface soil.

An increase in the quantity of roots in the subsurface soil was not consistently accompanied by an increase in yield of tubers.

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FROST INJURY TO CEREALS IN THE HEADING STAGE[1]

Coit A. Suneson[2]

THE recent distribution and widespread culture of the very early wheat variety Ramona has given California a new major production hazard—frost injury during the heading stage. Such damage has previously been infrequent and generally has been restricted to very early plantings. A similar situation in Argentina was reported by Rudorf and Job (5),[3] who stated that the culture of the early-maturing variety, 38 M.A., greatly increased the hazard from frost during heading. Frost damage at the heading stage has also been reported from Kansas (8) in Early Blackhull wheat.

Previous American workers, including Breithaupt (2) at Burns, Oregon, and Harlan and Shaw (4) at Obsidion, Idaho, reported damage from frost to cereals in heading as well as in the dough stage. Frost in the dough stage damages the appearance and often the quality of the grain. The writer has observed injury from frost in both the heading and dough stages in certain sections of Oregon and the northern mountain region of California. In these areas the hazard from damage at heading appears to be greatest with early varieties, but occasional summer frosts may injure either early or late varieties at any stage. Frost-damaged grain is virtually unknown in the grain-producing sections of California mentioned hereafter.

Evidence that frost injury at heading is not always recognized by agronomists and that it is of occasional importance in many parts of the country has prompted presentation of the observational and experimental data accumulated at the California Agricultural Experiment Station.

EXPERIMENTAL RESULTS

In California in 1940, severe frost injury at the heading stage occurred in commercial fields of Ramona wheat in Riverside County in February; in the Antelope Valley in March; and in the Shasta Valley in May. In 1939 similar damage resulted from a March frost in the San Joaquin Valley and a May frost in Shasta Valley. In field plot tests at Davis sown in November or December, frosts at the heading stage damaged Ramona in 3 of the 12 seasons from 1929 to 1940. In these seasons the estimated reductions in yield ranged from 30 to 60% despite a compensating growth of late tillers. Despite this damage, average acre yields of Ramona during the 12-year period have been satisfactory. The average yield of Ramona wheat was 46.8 bushels per acre, which was 3 bushels higher than that of the later-maturing Baart variety. These yields suggest that earliness is advantageous in the absence of frost, but they also show that "the plant breeders' ideal"—a consistently high-yielding variety—has

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[3]Reference by number is to "Literature Cited", p. 834.

not been attained with Ramona. Delayed planting would have evaded the frost injury encountered, but date-of-seeding tests, including those reported by Florell (3), show substantial yield reductions in all cereal varieties sown later than December.

Special nurseries have been grown for three years in order to secure late winter heading and comparative evaluations of frost injury among varieties of wheat and barley. In all experiments on frost injury, including those involved in the emasculation of greenhouse-grown plants by cold treatment (7), two pertinent features have always been evident, *viz.*, a comparatively short interval, ontogenetically, in which spikes are particularly sensitive to frost; and the frequent confinement of injury to the staminate flower parts.

Observed varietal variations and ranges in severity within these types are illustrated in Figs. 1 and 2. These particular injuries appeared after exposures to minimum field temperatures of 31°, 38°, and 28° on consecutive nights. The Finland variety apparently is representative of the Norwegian group of barleys mentioned by Harlan and Shaw (4) in which severe damage may envelope the entire spike while still down in the boot. The flower parts in this variety all show similar injury. In the Atrada barley variety, the glumes and awns and many of the pistilate flowers showed no injury when staminate flowers were killed, in which case the lodicules held the glumes open for several days. In the variety Ramona, partial dessication of some spikelets and self-sterility of others was common. The Pusa 4 variety was appreciably more frost-susceptible as shown by the severe dessication apparent after freezing of glumes and other flower parts. A similarity between some of these frost injuries and some common forms of injury resulting from heat and drought is apparent. There was evidence of differences in the length of the development interval during which the spikes were most susceptible to injury, as was also noted by Harland and Shaw (4). Furthermore, and in accordance with an observation by Bartlett (1) in New South Wales, spikes showing injury were shortened in height in various degrees, sometimes never emerging from the boot. Delay in flowering of injured tillers was also observed. These growth differences may be directly related to the dessication of conducting tissue below the spikes as evidenced by light-colored rings on some of the culms in Fig. 2.

The dates of heading of certain varieties of wheat and barley sown in the fall and winter of 1938–39 at Davis, Calif., are shown in Table 1. Ramona wheat and Vaughn barley are the earliest commercial varieties of these two crops now grown in California. Other varieties grown experimentally are even earlier. Certain of these varieties appear to have a slightly greater hardiness of all floral structures and a shorter, highly critical interval in development than that of Ramona These differences do not seem to be sufficient to encourage breeding for greater hardiness because variety differentiation appears to depend on temperature differences of only 2° or 3° F. A similar range between peach varieties (6), however, is being utilized in breeding and selection.

Partly sterile spikes containing self-fertile, self-sterile, and sterile florets similar to those shown for Atrada in Fig. 1 (center) were

studied to determine the influence of emasculation by frost upon natural crossing. Such spikes were obviously in good mechanical condition for wind pollination. Results with five varieties are given in Table 2. Varieties selected for study were grown in rows contiguous to other dissimilar varieties which escaped frost injury but which

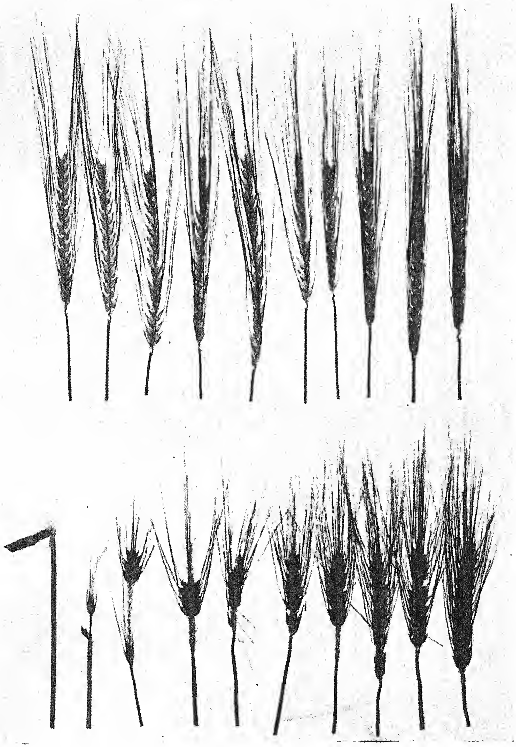

FIG. 1.—Range in frost damage to spikes of two varieties of barley. Atrada (above); Finland (below).

flowered while the frost-emasculated florets were receptive. Individual spikes were selected at random from those showing irregular seed

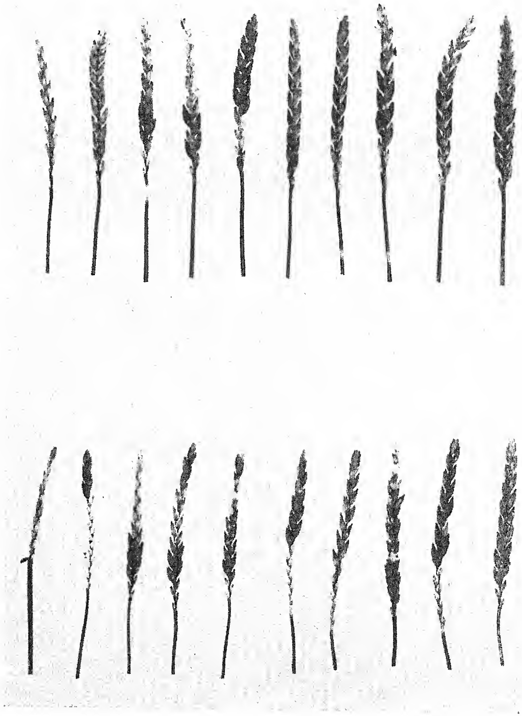

FIG. 2.—Range in frost damage to spikes of two varieties of wheat. Ramona (above); Pusa No. 4 (below).

sets on the spike. A surprisingly low incidence of natural crossing was observed in the progenies, which suggests that natural crossing as a result of frost emasculation is of little consequence under field condi-

tions. Plant characters among the varieties were sufficiently contrasting so that hybridity, if present, should have been evident in the F_1 generation.

TABLE 1.—*Heading dates of 10 varieties of wheat and barley sown on two or more dates at Davis, Calif., in the crop year 1938–39.*

Variety	C. I. No.	Dates of first heading for plants emerging on			
		Oct. 21	Nov. 22	Dec. 30	March 2
		Wheat			
Sunset	4728	1–15	—	—	5–5
Ramona	8241–1	2–16	3–30	4–18	5–7
Pusa No. 4	8899	3–1	4–10	4–22	5–9
Garnet	8180	3–11	—	—	5–13
Early Blackhull	8856	4–15	4–24	5–1	none
Baart	1697	3–28	4–22	—	5–24
		Barley			
Atsel	6250	12–15	3–1	4–1	4–27
Atrada	5636	2–20	3–29	4–6	5–4
Vaughn	1367	3–12	4–9	4–19	5–14
Club Mariout	261	3–20	4–18	—	5–20

TABLE 2.—*Incidence of natural crossing in normal spikes of barley and in spikes made partially self-sterile by frost as shown by subsequent classification of F_1 plants at Davis in 1937.*

Variety	C. I. No.	Average fertility of spikes used for seed, %	Hybrids observed in F_1 generation	Total number plants observed
Atsel	6250	100	0	99
Atsel	6250	30	4	175
Atrada	5636	100	1	84
Atrada	5636	20	0*	290
Stewart	6112	100	0	76
Stewart	6112	30	0	212
Mensury	5069	100	0	82
Mensury	5069	30	1	223
Mariout	3614	100	0	85
Mariout	3614	40	2	365

*Four albino plants were not considered as hybrids, though none were observed in the check.

SUMMARY

Frequent instances of frost damage at the critical heading stage suggest that a practical limit in earliness has been reached in California with the wheat variety Ramona.

Differences in spike or glume dessication and in differential flower part resistance to frost injury were observed among early varieties of wheat and barley grown experimentally. Breeding for protection against frost damage seems impractical, however, because the spread

in cold tolerance appears to be limited to temperature differences of only 2° or 3° F.

Frost damage to the staminate flower parts apparently does not increase natural crossing appreciably.

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YIELDS OF VARIETIES OF WHEAT DERIVED BY BACKCROSSING[1]

C. A. Suneson, O. C. Riddle, and F. N. Briggs[2]

THE backcross method of wheat improvement has introduced a number of innovations in plant breeding procedure. One of the most striking of these occurred when Baart 38 and White Federation 38 were increased and distributed in California without benefit of the extensive background of comparative yield trials which usually attends the introduction of an improved variety. This action was justified primarily by a theoretical consideration of the consequences of backcrossing (1, 2),[3] namely, that the yield, quality, and adaptation of the recurrent parents would be recovered. At the same time resistance to bunt, *Tilletia tritici*, and stem rust, *Puccinia graminis tritici*, could be added, which was the particular objective of this program. Pathological comparisons have adequately demonstrated the fulfillment of this last objective. Morphologic, ecologic, and a limited number of yield trials conducted during the progress of the breeding program indicated that the yielding ability of the commercial parents had been recovered, or that if differences still existed they were of such small magnitude as to be indeterminable in limited tests. It is now possible to supplement these preliminary tests with a considerable number of comparative yields from local, statewide, and regional sources.

VARIETIES AND TESTING METHODS

An understanding of the genetic relationship of the improved and commercial varieties under consideration is essential. White Federation 38 is a composite of 182 F_3 lines showing resistance to stem rust and bunt. Their breeding is shown by the pedigree (Martin × White Federation^6) × (Hope × White Federation^5). Baart 38 is a composite of 157 F_3 lines showing resistance to bunt and stem rust and produced from crossing (Martin × Baart^7) × (Hope × Baart^5). The numerical superscript denotes the number of times the commercial parent has been used in the crossing programs.

Only paired, contiguous field or nursery plots of the improved and commercial varieties are considered. These have been segregated from a somewhat larger

[1]Contribution from the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the Agronomy Department, University of California, Davis, Calif., cooperating. Acknowledgment is given for the cooperation of the Agricultural Extension Service in Lassen, Modoc, San Benito, Siskiyou, Solano, and Ventura counties in California, and Douglas and Washoe counties in Nevada with the above-named agencies in procurement of data. The results reported are of greatest immediate concern to these agencies operating where commercial production of the improved varieties has begun, but cooperation has also included the agricultural experiment stations in Colorado, Idaho, Montana, Oregon, Utah, and Washington participating in uniform nursery trials as a part of a cooperative regional wheat improvement program. Received for publication May 5, 1941.

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[3]Numbers in parenthesis refer to "Literature Cited", p. 840.

body of data to permit the specific comparisons herein considered. All nursery tests included in the calculations were standard three-row plots 16 feet long with rows spaced 12 inches apart. Yields were obtained by harvesting the center row of each plot. Field plots were 1/50 acre in size.

By utilizing the yields from University Farm at Davis, from the more extensive state-wide nurseries conducted in cooperation with county farm advisors in California and Nevada, and from uniform regional nurseries in other western states (6) in 1939 and 1940, a considerable body of data has been accumulated. The extreme ranges in geographical and ecological environments involved add materially to the value of the comparisons.

Two methods of statistical analysis have been used, both of which treat the data as paired comparisons. In comparisons involving t, the following formulae involving an adaptation of Student's method by Leonard and Clark (3) was used:

$$s^2 = \frac{S(d^2) - \frac{(Sd)^2}{N}}{N - 1} \quad \text{and } t = \bar{d}/\sqrt{\frac{s^2}{N}}$$

where s^2 is the variance of an individual difference and $\bar{d}$ the mean difference. The t value required for significance is for $N - 1$ degrees of freedom using Snedecor's (5) two-way table of t values to test the significance of the mean differences from zero. The more rapid point-binomial method (4) was also used. Odds by this method are dependent on distribution of differences irrespective of magnitude, and consequently, are suggestive of the character of the population sample.

PATHOLOGICAL RESULTS

No attempt was made during the course of development of these varieties or since to obtain yield data under disease conditions, because the difference in yield between the susceptible and resistant varieties would be in proportion to the severity of the epidemic. By accident, rather than design, some comparative yield data under stem-rust-epidemic conditions have been obtained, however. Thus for six California nurseries, each involving three paired replications of White Federation and White Federation 38, average yields of 40.9 bushels and 51.5 bushels per acre, respectively, were obtained. Mean differences in favor of White Federation 38 in these six nurseries ranged from 3.8 bushels to 23.2 bushels per acre, reflecting of course differences in the severity of the epidemics. Aside from such incidental data, the primary concern has been the relative resistance of these varieties.

BUNT

The resistance to bunt was obtained from the Martin variety as indicated above. Although Martin has been completely resistant to race 1, the race used at this station and the one commonly found in the state, 63 of the 182 lines which were bulked to make up White Federation 38 show a trace of bunt, that is, 1 infected plant among 60 to 80 healthy plants when heavily inoculated. It has been shown that such low incidence of bunt is of no commercial or pathological importance (7). Under the same conditions, White Federation showed

an average infection of about 60%. In Baart 38, only 15 of the 157 lines showed a trace of bunt, whereas Baart showed about 70% of this disease.

STEM RUST

The resistance to stem rust was obtained from the Hope variety. Resistant lines were selected under rust conditions so severe that White Federation, Baart, and susceptible hybrids were killed shortly after heading, with the result that their yields were cut practically to zero. Some of the lines which went into the composites were as resistant as Hope. Others produced a large number of very small sori under the above conditions. However, the sori appeared rather late and caused little injury as judged by the time of maturity and the appearance of the grain. It is believed that when such resistant varieties are grown on a wide scale, not enough inoculum will be produced to cause even this low infection.

In 1940, California experienced the worst and most widespread stem rust epidemic in a quarter of a century. In a number of localities White Federation 38 and Baart 38 produced normal crops where adjacent fields planted to their susceptible counterparts were so badly damaged that they were not harvested.

AGRONOMIC RESULTS

Results considered hereafter are from paired tests wherein bunt or stem rust did not affect yields. From such comparisons one can best determine the extent to which the most unique feature of the backcross method of breeding—recovery of the commercial type—has been met. The data herein reported seem especially well suited for this purpose because of the wide diversity in testing locations. These locations, together with frequencies of superior yield by the respective paired varieties during 1939 and 1940, are shown in Table 1. This method of comparison should permit a better comprehension of the character of the yield responses at the various locations than by the use of average yields. Detailed listing of the paired yields does not seem necessary.

Paired test yields permit the pooling of data into somewhat arbitrary groupings, such as shown in Table 2. Several other groupings were studied, but results were substantially like those reported. As shown in Table 2, neither the t value derived by Student's pairing method, nor the odds obtained by the point-binomial method reveal any significant difference between White Federation and White Federation 38 in any group of tests. The close agreement in the yields of White Federation and White Federation 38 in 102 comparisons drawn from eight states indicates strongly that they are alike in their net yield reaction where stem rust and bunt were not present.

Comparisons of Baart and Baart 38, on the other hand, as shown in Tables 1 and 2, are not so consistent or conclusive. In 40 experiments in California, there is no evidence of a difference in yield between the two seed stocks. In the regional irrigated nursery tests, however, there is a suggestion of a significant yield difference in favor of Baart, as indicated by significant odds by the point-binomial method,

though not by Student's method. Lack of agreement between odds determined by Student's method and by the point-binomial method suggests that the distribution of difference magnitudes is not normal. Breakdown of this data into smaller groupings has not contributed to a better understanding of the problem for the near-significance here reported is characteristic of most of these data. Whether the above results are due merely to sampling errors, or to a real but relatively small difference in yielding capacity in the absence of rust and bunt cannot be determined with certainty without additional testing.

TABLE 1.—*Frequency of superior yields of varieties in comparable paired tests in western states in 1939 and 1940.*

Location	No. of times superior			No. of times superior		
	Baart	Baart 38	Tie	White Federation	White Federation 38	Tie
Davis, Calif. (field plots)	5	5	–	3	6	1
California county nurseries	11	17	2	3	6	–
Regional nurseries:						
Irrigated stations:						
Hesperus, Colo.	1	2	1	3	2	–
Aberdeen, Idaho	4	—	–	2	3	–
Bozeman, Mont.	4	—	–	3	2	–
Logan, Utah	3	—	–	2	3	–
Nevada counties	5	4	–	4	2	–
Dry land stations:						
Davis, Calif.	2	1	–	2	1	–
Moscow, Idaho	2	1	–	1	2	–
Sandpoint, Idaho	2	3	–	3	3	–
Tetonia, Idaho	5	1	–	1	5	–
Moro, Ore.	4	2	–	4	1	1
Pendleton, Ore.	2	4	–	—	5	1
Union, Ore.	2	1	–	1	2	–
Lind, Wash.	1	4	1	5	—	1
Pomeroy, Wash.	2	3	1	3	3	–
Pullman, Wash.	3	3	–	4	2	–
Walla Walla, Wash.	4	2	–	5	1	–
Total	62	53	5	49	49	4

As further evidence that the commercial types have been recovered without material change in both Baart 38 and White Federation 38, no significant differences in plant height, date of heading, or in reaction to diseases other than stem rust or bunt, have been observed in the paired tests reported in Tables 1 and 2.

SUMMARY

Two varieties resistant to stem rust and bunt but otherwise very similar to Baart and White Federation, the recurring parents, have been produced by backcrossing. These are designated as Baart 38 and White Federation 38. Stem rust resistance was secured from the hard red spring variety Hope and bunt resistance from Martin.

TABLE 2.—*Comparison of yields of Baart with Baart 38 and White Federation with White Federation 38 in different groups of tests during 1939 and 1940.*

Group	Mean yield in bushels per acre			Number paired comparisons	t value	t required for significance at 5% point*	Odds, point binomial method†
	Commercial type	"38" type	Difference				
			Baart vs. Baart 38				
Davis, Calif. field plots	34.5	34.9	0.4	10	0.237	2.262	Low‡
California county nurseries	33.0	35.1	2.1	30	1.361	2.045	Low
Regional nurseries:							
Irrigated stations	48.8	46.1	2.7	24	1.818	2.069	>19:1
Dry-land stations	30.2	29.2	1.0	56	1.502	2.004	Low
All tests	35.0	34.5	0.5	120	0.746	1.980	Low
			White Federation vs. White Federation 38				
Davis, Calif. field plots	29.4	32.7	3.3	10	1.053	2.262	Low
California county nurseries	47.7	50.4	2.7	9	1.604	2.306	Low
Regional nurseries:							
Irrigated stations	59.2	58.2	1.0	26	0.536	2.060	Low
Dry-land stations	29.8	30.0	0.2	57	0.258	2.003	Low
All tests	38.8	39.2	0.4	102	0.572	1.984	Low

*Interpolated for values not given in tables of t.
†Odds against the occurrence of the same results, i.e., *m* times superior in *n* trials, by chance alone.
‡Less than 19:1.

In limited experimental trials under stem rust epidemic conditions, these new varieties produced materially larger yields than their counterparts and in the severe epidemic of 1940 commercial fields produced normal yields, whereas in some cases adjacent fields of Baart and White Federation were so badly damaged that they were not harvested.

In 102 experimental trials in which neither stem rust nor bunt affected yields, no significant differences between White Federation and White Federation 38 were observed irrespective of whether significance was tested by Student's pairing method or by the point binomial method. One-hundred-twenty similar comparisons of Baart and Baart 38 likewise failed to show a significant difference in yield, although at some stations the level of significance was closely approached.

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MORE THAN LIME BENEFITS IN RUFFIN'S RESULTS[1]

E. O. Fippin[2]

EDMUND RUFFIN of Virginia has agricultural fame for his achievements in the second quarter of the nineteenth century in the use of liming materials and his authorship of a 500-page "Essay on Calcareous Manures" and other voluminous writings. Professor Emil Truog, as president of the American Society of Agronomy in 1938, featured the work of Ruffin in his presidential address (3)[3] under the title "Putting Soil Science to Work." With extensive quotations from a biographical sketch of Ruffin by Avery Craven (1) and comments of his own, Professor Truog emphasized the pioneer work of Ruffin in soil chemistry, soil management, and particularly in demonstrating the value of the Coastal Plain shell marls.

The evidence seems to be unmistakable that by the use of these marls and good husbandry, Ruffin was able to double and triple his yields of crops, especially clover. He writes that clover grew so large it scarcely could be cut with his machines. The question is, was it liming materials alone that made Ruffin's results possible, or were there some other nutrients in the marls used that made important contributions to the results achieved? Professor Truog's stress on the liming aspect of the results of Ruffin's practices is justified by the main title and theme of Ruffin's writings—Calcareous Manures. It is worthwhile, however, to examine the facts more closely.

From five years' residence at Richmond, Virginia, and from earlier soil survey field experience in Prince George County, Maryland, the writer became acquainted with the general geological and soil features of the Coastal Plain-Piedmont belt of that region. The soils of the western Coastal Plain belt of Virginia give every evidence of being low in phosphate and relatively low in potash as well as in lime, and thus would not be expected to give such increased yields merely from the use of shell lime alone. On the other hand, underlying those western Coastal Plain soils, from New Jersey to South Carolina, are extensive beds of "greensand" as well as "shell marl." Unevenly distributed in the greensand is glauconite—rich in potash—which contributes to the green color of the greensand. Many of the beds also contain a considerable percentage of calcium phosphate and calcium carbonate derived from the bones, teeth, and shells of marine animals which, with the glauconite, compose a "greensand marl." As the writer read Professor Truog's address the question arose, Could it be possible that greensand was associated with the shell marl used by Ruffin, so that he had a lime, phosphate, and potash fertilizer—an ideal combination for clover—instead of merely a source of liming material?

From a determination of the location of the Coggin's Point and Marlbourne plantations of Ruffin and from a check with the State

[1]Received for publication May 12, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 848.

Geologist, Doctor Arthur Bevan, as to the occurrence of greensand and shell marls at the site of Coggin's Point, it seemed probable that there is a close association of the two materials. This led to the decision to inspect those properties at the first opportunity and, if possible, to examine the pits from which Ruffin secured marl. The fall of 1940 was the first opportunity for this examination. Both plantations were visited with Dr. H. J. Eckenrode, State Historian.

FIG. 1.—Section of shell beds above and greensand below in creek bank on Coggin's Point plantation from which samples 1, 1a, and 2 were taken.

Ruffin's original plantation at Coggin's Point is on the south side of the James River, 6 miles east of Hopewell. The exact pits used were not definitely located, but the occurrence of heavy marl beds in the river bank and their occurrence generally underlying the plantation some feet below the general surface was established. These beds were examined in the ravines of small streams that flow from the farm into the river. The underlying formation is the Nanjemoy, which characteristically contains much greensand (4).

Fig. 1 is a picture of an exposure of these beds showing the heavy shell layer above, and a less shelly and more nearly greensand material below.

Marlbourne plantation on the Pamunkey River, 20 miles northeast of Richmond, was acquired by Ruffin in 1840. We were shown the pits worked by Ruffin at the head of a small stream. These pits now are sifted over with a heavy layer of sandy material that generally overlies the marl here to a depth of 6 to 10 feet. The marl is exposed in the banks and bed of the stream where it was examined. The Nanjemoy formation, as seen here, is less shelly and has a larger proportion of greensand marl than the Coggin's Point beds. Fig. 2 is a poor photo-

FIG. 2.—Top of greensand, marked by handkerchief, on Marlbourne plantation from which sample 7 was taken. The white flecks are shell fragments. About 6 feet of siliceous sandy loam here overlies the marl which is many feet thick.

graph of one of these sections, showing the contact, marked by a white handerkerchief, of the marl with the overlying sandy formation.

Samples were taken of several strata of these greensand and shell beds at both plantations, and chemical analyses were made by L. J. Hardin of the University of Tennessee under the supervision of Doctor W. H. MacIntire, with the results shown in Table 1.

TABLE 1.—*Analyses of marls from Edmund Ruffin plantations, Virginia.*

Plantation	Sample No.*	$CaCO_3$ %	P_2O_5 %	K_2O %
Coggin's Point........	1	34.50	0.4	0.20
Coggin's Point........	1a	12.50	0.50	0.2
Coggin's Point........	2	12.	0.3	0.2
Coggin's Point........	3	34.50	0.27	0.2
Coggin's Point........	4	15.	0.28	0.20
Marlbourne..........	5	27.50	0.08	0.2
Marlbourne..........	6	5.50	0.08	0.2

*1, highest level of beds mostly shells, Coggin's Point; 1a, taken from inside of a shell from sample 1; 2, same location as sample 1, from lowest part of cut; 3, 75 feet down stream from samples 1 and 2, and several feet lower but from upper part of formation at that point; 4, same location as sample 3, but from lower part of formation (see Fig. 1); 5, from highest point on stream where marl was observed at Marlbourne. Shell beds similar to Coggin's Point; 6, 200 feet down stream from sample 5. Much less shelly. (See Fig. 2.)

TABLE 2.—*Analyses of E. Ruffin's samples of Virginia greensand.**

Sample No.	Carbonate of lime	Phosphate of lime	Sulfate of lime	Sulfate of iron
1....................	——	0.25%	——	——
3....................	1.55	0.25	0.813	3.07
6....................	0.535	0.25	0.661	2.06
9....................	2.350	——	2.310	5.82
10†..................	56.00	0.84	——	——

*By Charles U. Shepard, Yale University.
†Several thin layers of compressed shells 1 to 3 inches thick associated with sample 9.

These analyses reveal from 13 to 35% of calcium carbonate and from 0.1 to 0.5% of P_2O_5. As to potash, the analyses reveal a low content, but only one actual determination was made and the others were estimated from observation of the uniformity of the analytical precipitates. Apparently the collected materials are not rich in glauconite, a mineral which sometimes contains as much as 10% of potash and which is a common constituent of the Nanjemoy formation in many places.

Since visiting the Ruffin plantation, the writer has reviewed the fifth edition of Ruffin's "An Essay on Calcareous Manures"(2), which was a highly interesting experience. The essay reveals Ruffin's keen powers of observation and analysis, his systematic habits as an experimenter, and his abilities as a successful, practical farmer.

As Professor Truog points out, Ruffin as a young man, responsible for the management of a lean, failing plantation, came upon a suggestion in Davy's *Agricultural Chemistry* that infertile soils may contain mineral acids that can be corrected by liming materials. This started him on his chemical studies in which he seems to have attained quite a degree of proficiency, considering his limited facilities. These investigations revealed that the shell beds he found in the river and creek banks on his plantation might be used to advantage on his soil. This use he started in the early 1820's.

As early as 1830, Ruffin recognized (2, page 162) that not all his improved crop yields from the use of marl could be attributed to its liming material. He writes:

> "The fact that the effects of calcareous manures so generally exceed in measure the supposed power and operation of the causes, and more especially in regard to neutral soils, seemed to indicate that calcareous manures possessed other fertilizing powers, besides those set forth in Chapter VIII."

From his acquaintance with the practices of other planters, he knew that burned lime used on the Piedmont lands above the "Fall line" at Richmond did not produce the effects secured from the shell marls.

At first he attributed its notable effects on clover to the sulfur in the small proportion of crystals of gypsum that he detected in the marl. In the 1830's he wrote (2, page 143) with reference to an application of material from a particular strata:

> "The calcareous ingredient, on a general average carefully made, was found to be 62 percent. If this manure had been used before its gypseous quality was discovered, all its effects would have been ascribed to calcareous earth alone, and the most erroneous opinions might thence have been formed of its mode of operation."

But in later years, from his own and his neighbor's experience with Nova Scotia and French gypsum, he came to the conclusion that shells and gypsum were not sufficient to account for all the effects he observed.

He recognized wide differences in the chemical composition of

different layers of these marl beds on his own and other plantations, and that applications of these different materials were associated with differences in crop yields. He states further (2, page 329):

"Next below this stony layer is the greensand earth, of great and unknown depth. Here, this contains only 2 or 3 percent of carbonate of lime, in a few widely dispersed shells, with the usual and considerable proportion of greensand."

Ruffin was something of a mineralogist. As early as 1830, he became acquainted with "greensand". He recognized glauconite in the various strata of his marls and isolated and examined this material. He conceived (2, page 458) it had some value to crops, and he writes:

"The inferences which I drew from all my experiences, were that this earth as manure acted in the same manner as gypsum, though more powerfully—and in no other manner than as gypsum would under like circumstances; that like gypsum, on my land certainly, and as I inferred in our tide-water region generally, this earth had no effect whatever on any acid soils—and rarely on any other crop than clover, even when properly applied on neutral or calcareous soils; and that when naturally acid soils were made calcareous by being marled, this green earth then became generally operative thereon as a manure for clover, in the same manner as is usual in regard to gypsum."

In 1842 he sent samples of several strata of marl to Professor Charles U. Shepard of Yale University for chemical analyses. Shepard quoted the analyses by M. Berthier of glauconite nodules from French greensand showing 10% of potash. Dr. Shepard's report (2, page 469) on his analyses of the Ruffin samples is summarized in Table 2, and did not include a report on potash.

Thus the evidence seems to be clear, both from our own examination and analyses of the formations and from the published observations and analyses of Ruffin, that the marl beds used were not merely shell beds but were shell beds in association with greensand marl, all of varying degrees of purity and association of greensand and phosphatic material. The material used was in fact a very complete though low-grade mineral fertilizer embracing 30 to 60 % of lime carbonate, 0.25 to 0.7 or 0.8% of phosphate of lime, potash from glauconite in the greensand, and intermixture of gypsum crystals, not to mention minor nutrients now known often to be of value. Such a material, we know, is especially suited for the growth of clover on acidic soil.

The marls were reached by pits or by excavation into the river bank and were applied at low cost by the use of slave labor on which Ruffin reports (2, page 319) extensive figures.

RUFFIN AS A PRACTICAL FARMER

Ruffin was a good, practical farmer as well as a student, who pursued his methods in a scientific manner. He kept systematic records of the treatments used and drew many of his conclusions from weights and measurements of the resulting crops. He read widely for his time and was a keen observer. He knew the value of manure, of crop rota-

tions, of thorough tillage, of the prevention of erosion, and of clovers and other legumes, and used them in his practice, as a result of which he became highly prosperous. He observed some of the bad effects of too much liming material applied to the soil. For the shell material, high in calcium carbonate, he set about 250 bushels as the limit of safety on his sandy soil, except for clover. Of the more purely greensand material, he considered much larger applications as permissible and desirable. Some of his statements on the fertilizing value of clover are worth noting here as examples of the pioneering character of his observations. He challenged the opinion held at the time by Leibig (5) that legumes are able to secure substantial amounts of ammonia from the atmosphere because of their broad leaves. He noted (2, page 258) that many other broad-leaved plants do not have this nitrogen-gathering power. He writes:

> "It has long been a received and unquestioned opinion among intelligent farmers, that the growth of clover, and other leguminous crops, drew away from the soil less of the fertilizing principles, and returned to it more, than any others." x x . "In either case, it is generally believed that the product of the second crop of wheat, sown upon clover turned under as manure, is usually about double that of the first crop of wheat following corn, though the immediately preceding corn crop had received all the prepared putrescent manure used."

Ruffin sums up his conclusion (2, page 262) thus concerning clover:

> "In the preceding pages I have endeavored to explain and to establish these opinions:
>
> 1. That azote (nitrogen), the smallest but richest, and for its quantity by far the most important element and ingredient of plants, is derived by most plants exclusively from the soil;
>
> 2. That plants of the leguminous tribe, and they alone, so far as known, possess and exert the power also to draw azote directly from the atmosphere, assimilate and fix in their bodies this richest material, and to give it as manure to the soil on which they grow, and are left to decay;
>
> 3. That owing to this peculiar power, leguminous plants are the most highly enriching to soil, as manure."

This observation was more than 40 years before Hellriegel and Wilfarth established the causal relation of symbiotic bacteria on the roots of legumes as the agency through which such plants are able to use the nitrogen of the air.

Ruffin's combination of shell marl with greensand marl, either from mixture with the shells or applied separately, in even larger quantity, together with clover, the careful use of farm manures, and a systematic rotation of legumes, with grains would be approved by the best modern agronomists as good practice. As Ruffin points out, the adoption of these practices by large numbers of planters in the Coastal Plain region, made possible by the underlying marls, greatly raised land values of a large region.

The only indication we find in "Calcareous Manures" that Ruffin appreciated the value of the phosphate in the materials used is in the last part of the following extract (2, page 480), which paragraph is quoted as a good example of his observations, practices, and scientific thinking:

"But since I have discovered good marl, of workable thickness, on Marlbourne farm, I have carried out all the overlying olive earth (greensand), though it is more sandy here than is usually found. I had begun this course before having heard of any useful effect of such application. But since, I have learned very remarkable effects of other olive earth, as tried by two neighboring farmers, Messrs. Henry Jones and John Beale. The most accurate and conclusive of these trials was an application of this earth alone, 400 bushels to the acre, on still and poor land. The application was made for the corn crop of 1850, and produced not much, if any, perceptible effect. The benefit was much greater, though still small, on the succeeding crop of wheat. But of the next following clover, which I saw in May and June, 1852, the growth was more luxuriant than any on the richest other land; and the effect of the olive earth alone, was greater on the clover than from marl, with its unquestionable accompaniment of gypsum, or other manure elsewhere on similar lands of this neighborhood. Still, I believe that gypsum is the principle manuring principle—and that these wonderful effects will therefore be confined mostly to clover, during its temporary action. The remains of bones and teeth also are more numerous in this olive earth (immediately above the marl) than anywhere lower; and hence this layer, apparently, is *better supplied with phosphate of lime*—a manure of very great and peculiar value for other crops, and especially for wheat."

Even more than on the basis of use of calcareous manures, Ruffin's observations, investigations, and farm practices entitle him to recognition for having "Put Soil Science to Work."

SUMMARY

1. From the known character of the soils in the upper Coastal Plain of Virginia and their apparent deficiency in available phosphates and potash and probably sulfur, as well as their acidity, it is not to be expected that the phenomenal increases in crop yields secured by Edmund Ruffin and his associated planters could have been secured from the use of carbonate of lime alone.

2. Examination and chemical analysis of the marl deposits used by Ruffin on his soil and examination of his writings both seem to indicate beyond question that the results secured were not due to the liming materials of the shells alone, as sometimes supposed, but were due to the association of the shell deposits with greensand marl carrying considerable, though varying proportions of phosphate, of lime, probably in some strata, potash, and gypsum, a combination especially adapted to promote the growth of clover.

3. This fact detracts in no way from the credit due Ruffin for having been a pioneer in "Putting Soil Science to Work", as emphasized by Professor Truog, for Ruffin was a keen observer, scientifically systematic in his methods, and a good practical farmer and business man, as is revealed by his volume on "Calcareous Manures." He is entitled to special credit for his pioneering observations and conclusions as to the basis of the manural value of clover and other legumes through the derivation of a large part of their nitrogen from the atmosphere.

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NOTES

FIELD SEED CLEANER FOR SOYBEANS[1]

MOST large and heavy-seeded crops, such as soybeans, require a relatively simple threshing device. As seed cleaning devices constructed in the thresher usually render the machine more difficult to clean, it has been found advantageous to construct this cleaning equipment separate from the thresher.

A relatively simple type of cleaning device which has given excellent results during the past season with soybeans is shown in Fig. 1. As shown in Fig. 2, a forge blower mounted on the thresher is operated from the crank shaft pulley of the small gas engine which operates the thresher. The cleaner consists of a ⅓-inch mesh screen mounted in a suitable metal frame so as to allow the haulm and bean mixture to be shaken by oscillating the screen assembly. All material passing through the screen passes down an inclined chute and encounters a blast of air which is conducted from the forge blower to the cleaner through a flexible 4-inch tube. Chaff and dust are blown up the chute and out of the cleaner (Fig. 1 A), while the seeds roll down into a funnel-shaped receptacle to which a bag mat be attached.[2]

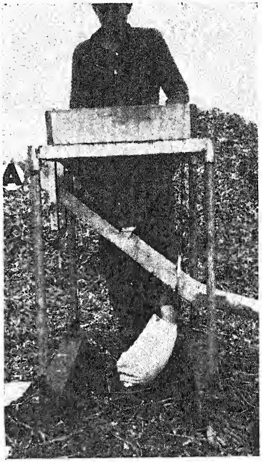

FIG. 1.—Field seed cleaner. A, chaff exit.

The air-blast is regulated to accomplish the separation by means of a slide on the blower. A butterfly valve in the air tube near the cleaner permits shutting off of the air-blast momentarily after each sample is screened, thereby allowing any light seeds, which may be held in the chute due to equili-

[1]Contribution from the U. S. Regional Soybean Industrial Products Laboratory, U. S. Dept. of Agriculture, and the Farm Crops Subsection of the Iowa Agricultural Experiment Station, Ames, Iowa. Jour. paper No. J-889 of the Iowa Agricultural Experiment Station, Project 186.

[2]Both operators should wear a respirator equipped with a wide-vision eye shield to protect both the eyes and respiratory organs against dust and fine particles. As small stones in the thresher sometimes cause fire, and the gasoline in the engine fuel tank gets quite hot when the engine is in operation, and the bean vines are dry and inflammable, it is suggested that a 7-pound Dugas or CO2 hand fire extinguisher be located at an accessible point near the operation. A metal screen and frame guard enclosing the motor and belt drive would add to the safety in operating the equipment.

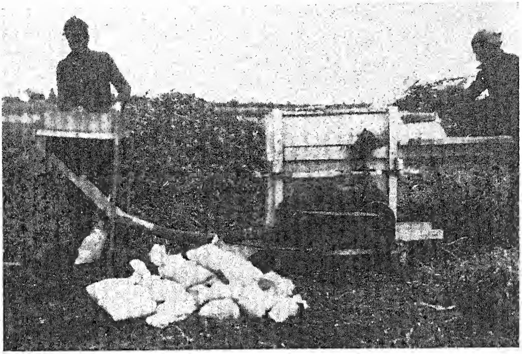

FIG. 2.—Field seed cleaner in operation with soybean nursery plot thresher.

brium between the air current and gravity, to roll down into the receptacle. The cleaner is completely collapsible which facilitates moving it from field to field.

This device has permitted cleaning samples in the field with no danger of mixing. Elimination of the cleaning operation in the laboratory during one season has more than compensated for the cost of the equipment. It was built by an Ames, Iowa, machinist at an approximate cost of $30.00 exclusive of the blower.—MARTIN G. WEISS, *Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, Ames, Iowa.*

ARTIFICIALLY INDUCED VIVIPARY IN BARLEY

VIVIPARY in *Zea mais*[1] is accepted as a heritable character. In *Andropogon sorghum*[2] immature seeds have been observed to germinate on the growing panicle when subjected to a rain and subsequent humid weather. In the small grains, sprouting in the shock often occurs. The last, however, is probably not vivipary, since presumably the grain had attained binder ripeness and had undergone some measure of drying after harvest.

In two varieties of common barley, Manchuria (*Hordeum vulgare pallidum*) and Hannchen (*H. distichon palmella*) growing in the greenhouse at Arlington Experimental Farm, it has been found possible to secure germination of very immature seeds while still attached to the growing plant. This was accomplished by affording an abundant supply of water to the caryopsis directly over the embryo. The embryo

[1]EYSTER, W. H. Genetics, 16:574–590. 1931.
[2]AYYANGAR, G. N. R., and PANDURANGA RAO, V. Curr. Sci., 3:617–619. 1935.

areas of the seeds were uncovered by removing the overlying lemma, care being taken to preserve intact the outer epidermis of the caryopsis. Narrow strips of filter paper were inserted over the embryos and held in place by the seeds just below. The spike was then wrapped in a layer of absorbent cotton or filter paper with a wad of cotton over the top and the whole enclosed in glassine paper. Water siphoned by drops from a container supported above the plant was supplied to the wrapping and was conducted by the filter paper strips to the surface of the embryo. The results are shown in Table 1.

TABLE 1.—*Effect of treating barley to induce vivipary.*

Age at treatment*	No. of spikes	Number of seeds	
		Treated	Germinated
	Manchuria		
15	3	27	20
13	1	9	8
10	3	14	11
	Hannchen		
10	3	29	21
9	2	18	15
8	1	7	7
7	1	9	8
6	1	9	6

*Days after pollination.

On one spike treated 9 days after pollination, four seeds were found germinated on the sixth day after treatment. The 6-day Hannchen spike flowered on April 10, was treated on April 16, one seed showed an extended plumule on April 25, and on April 29, 19 days after flowering, six of the nine treated seeds had germinated.

An occasional seed with lemma intact showed germination.

Of 16 seedlings from treated seeds that were planted in pots in the greenhouse, only 1 (an albino) failed to produce normal plants.

By this method it was possible to secure transplantable seedlings in 15 to 20 days after flowering. The procedure should be useful in accelerating operations in a breeding program.—MERRITT N. POPE, *Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture, Washington, D. C.*

A RAPID METHOD OF DETERMINING THE TOTAL CARBON CONTENT OF SOILS USING PERCHLORIC ACID

PRESENT-DAY determinations of soil organic matter are accomplished mainly by the wet combustion method, involving the reduction of chromic acid. A much less frequently used method is the combustion or ignition method, involving the use of a gas or electric combustion chamber. The latter method is the more accurate, but combustion furnaces are expensive and many laboratories can-

not afford them. In addition, the combustion method is slow and requires more than a half hour per determination.

The chromic acid wet combustion method of determining soil organic matter is inexpensive and fairly rapid, when a setup for analyzing a large number of samples is used. However, this method has several admitted, inherent weaknesses. It is known that it quite frequently does not check with the combustion furnace method. Such discrepancies, which occasionally are wide, are mostly explained on the basis that, since the principle involves the reduction of the chromic acid, there is something in the soil besides the organic matter which can cause the reducing reaction in the acid. Furthermore, it is seldom known when soils containing such extraneous reducing substances are to be encountered and discrepancies cannot be predicted.

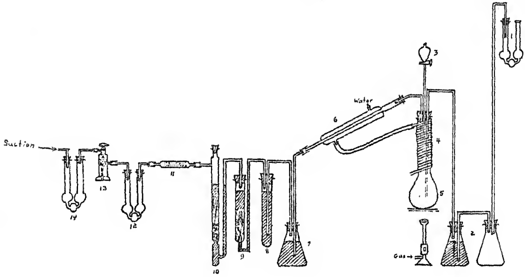

FIG. 1.—Apparatus for the determination of total carbon.

In Oklahoma, such erratic soils are met with quite frequently. Accordingly, an attempt was made at the Oklahoma Agricultural Experiment Station to develop a rapid, inexpensive, simple method of soil organic matter determination which would obviate uncertainties. The use of perchloric acid as an oxidizing agent suggested itself and a train, similar to that used in the combustion furnace method, was set up as shown in Fig. 1. Since chlorine gas is evolved from the perchloric acid, a tube containing an absorbent for this gas and a detector tube of silver sulfate solution (to show when the absorbent is saturated) are placed in the train. A comparison of the perchloric acid method with other methods for determining soil organic matter is presented in Table 1.

The train is constituted as follows:

1. Absorption tube, filled with granulated soda lime to remove carbon dioxide from the incoming air.
2. Two 300-ml Erlenmeyer flasks, one of which is nearly filled with tap water and the other left empty as an overflow vessel. Any back pressure generated in the heating flask is thus buffered.

TABLE 1.—*Comparison of methods of determining organic matter in soils expressed as percentage of organic matter.*

Soil sample No.	Chromic acid digestion	Combustion furnace (ignition)	Perchloric acid digestion
	Upland Soils		
3993	1.45	1.37	1.35
4005	1.04	0.97	0.98
4052	1.16	1.08	1.05
6529	2.37	2.23	2.21
6559	1.71	1.45	1.47
	Soils Affected by Natural Gas Leaks		
6447	8.94	7.40	7.34
6449	9.30	4.15	4.19
6465	5.96	4.74	4.71
6467	6.28	4.40	4.42
6469	3.13	2.33	2.32
	Bottom-Land Soils		
a	1.92	1.70	1.70
b	2.46	2.11	2.08
c	2.33	2.02	2.03
d	3.71	2.45	2.42
e	2.90	2.22	2.18
	Prairie, Virgin		
f	3.77	3.06	3.07
	Prairie, Cultivated		
g	2.31	1.70	1.73

3. Separatory funnel for introducing the oxidizing acid mixture into the digestion flask.
4. Copper coil wound around neck of flask and through which water from the glass condenser circulates to cool the top of the flask. This prevents the fumes from becoming hot and attacking the rubber stopper in the top of the flask. The gasoline line from most any old car is very suitable for this purpose.
5. Heating flask, using an ordinary 500-ml Pyrex kjeldahl flask. An 800-ml flask is even more suitable.
6. Glass distillation tube used to condense fumes from the heating flask.
7. Erlenmeyer flask containing acidified water to catch condensation from heating unit.
8. Tube containing saturated alcoholic solution of para-nitroso-dimethylaniline which absorbs the evolved chlorine and any hydrochloric acid fumes that might come over.
9. Tube containing a saturated solution of silver sulfate to detect when the absorbent in tube 8 becomes saturated. It contains some glass wool on the bottom to aid absorption.
10. Absorption tube containing constant-boiling sulfuric acid to remove moisture and sulfur fumes. Glass beads and glass wool placed in the tube aid in breaking up the up-surging bubbles and increase absorption surface.
11. Small tube containing 20-mesh granulated zinc to remove any traces of excaped sulfur trioxide.

12. Absorbing tube containing dehydrite to catch any possible traces of moisture that may have come thus far in the train.
13. Stetser-Norton absorption bulb containing ascarite in which the carbon dioxide from the oxidation of the organic matter is combined. This bulb is easily disconnected for weighing the carbon dioxide.
14. Absorption tube containing dehydrite to prevent the interference of any moisture from the suction line, which is attached to this tube.

All parts, or components, of the train may be stabilized or made secure according to the ideas of the operator, using ringstands or other available equipment which can be adapted to the purpose.

Procedure for organic matter determination:

A 1-gram sample of soil is placed in the kjeldahl flask.[1] In the case of peats or mucks, one-half of this amount is sufficient. If carbonates are present, the soil should, of course, be acid pretreated. After the soil has been placed in the flask, the stopper through which the stem of the separatory funnel is run is placed securely in the top of the kjeldahl flask.

The system is now aerated, without component No. 13 being connected, for about 5 minutes, or less, according to individual experience. The rate of aeration should be regulated so that no splashing of any of the liquids in the train occurs. About five bubbles per second through tube 10 is sufficient.

The Stetser-Norton bulb (component No. 13) is now connected to the train and the system closed. Twenty-five ml of concentrated c.p. sulfuric acid, containing 0.200 ml of 70% perchloric acid (0.500 ml for peat) are let down into the kjeldahl heating flask through the separatory funnel. Suction is now started carefully and a small flame placed under the digestion flask. The heating should also be done carefully and a micro burner is ideal for the purpose.

After heating has taken place for 3 to 5 minutes, a very rapid decomposition of the perchloric acid takes place. The flame should be removed quickly and the suction of air through the train should now be regulated to prevent too much back pressure into component 2 of the train. When this reaction has subsided, the flame is replaced and heating continued for 2 or 3 minutes. At this time the flame is extinguished and aeration allowed to continue for about 5 minutes. At the end of this time the suction is stopped, the ascarite bulb weighed, and the increase in weight calculated as carbon dioxide given off by the oxidized soil sample. To compute as percentage total carbon, the weight of carbon dioxide found is multiplied by the factor 27.27; to calculate as percentage organic matter, multiply this weight by the factor 47.014.

As the ascarite takes up carbon dioxide, it becomes distinctly lighter in color. This enables the operator to determine readily when the material becomes completely "used up" and the bulb should be recharged with ascarite. The charging is done as follows: The bottom

[1]It was found that adherence of soil to the neck of the flask could be avoided by placing the sample in an abbreviated test tube of Pyrex glass and letting the tube and all slide carefully down the inclined neck of the flask. The tube, which does not hinder digestion, can be made by cutting off the bottom inch, or so, of a test tube ½ inch in diameter.

of the bulb is covered with a thin layer of absorbent cotton. On this is placed a half-inch layer of 8-mesh ascarite. Above this is placed a 1-inch layer of 20- to 30-mesh ascarite and on top of this another ½-inch layer of 8-mesh ascarite. The remainder of the bulb is now filled with dehydrite to absorb any moisture that might be lost from the ascarite.

Should any precautions in procedure be necessary, they might be taken as follows:

1. Maintain constant air flow through train. The proper rate may be determined by experience.

2. Remove or control flame at the instant chlorine gas begins to evolve in heating flask until reaction ceases.

3. Change the constant-boiling sulfuric acid when necessary, as determined by experience. Used acid may easily be recovered by boiling it sufficiently.

4. Change the chlorine absorbent when the silver sulfate solution indicates presence of chlorides. Fifty ml of this absorbent is usually sufficient for 25 determinations.

The above-described method of determining organic matter in soils gives results which compare very favorably with those produced by the gas or electric combustion furnace, as shown by the data in the accompanying table. Furthermore, determinations can be completed in approximately half of the time required by the combustion furnace method.—M. J. Plice, *Oklahoma Agricultural Experiment Station, Stillwater, Okla.; and* Jesse Lunin, *U. S. Soil Conservation Service.*

RIBBED PASPALUM, PASPALUM MALACOPHYLLUM[1]

The first introductions of *Paspalum malacophyllum* Trin. were made in 1921. F. C. 03490 came in indirectly from Brazil under the name *Andropogon scaberrimus* (Nees) Kunth, but plants grown from this seed were identified as *P. malacophyllum*. F. C. 04240 was received from Argentina as *P. malacophyllum*. They were first grown at McNeill, Miss., in 1924 where they made good growth. In 1929, 10 plants each of F. C. 03490 and F. C. 04240 were sent to Tifton, Ga., and to Gainesville, Fla., where they developed rapidly. They resembled Dallis grass somewhat in growth habit. The preliminary tests indicated that *P. malacophyllum* is a promising hay and pasture grass, and seed was increased for more extensive tests which began in 1936.

Ribbed paspalum is a perennial, semi-upright, bunch grass growing to a height of 3 to 4 feet, the leaves and stems are fine, being smaller than Dallis grass, with the greater mass of leaves on the lower 12 to 16 inches of the plant. The leaves are hairy and usually yellowish green in color, remaining tender throughout the summer. Many panicles 4 to 5 inches long are produced and one plant may

[1]Cooperative investigations of the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, and the Georgia Coastal Plain Experiment Station, Tifton, Ga.

have all stages of seed formation from tillers not yet headed, to flowers, immature seed, ripe seed, and dry panicles from which the seed has already shattered. The seed (fertile lemma) is distinctly ribbed, hence the name "ribbed paspalum."

Ribbed paspalum is adapted to upland soils, either sands or clay, and, in competition with other grasses, will make fair growth on soils low in fertility. At Tifton, Ga., on average Tifton fine sandy loam soil, response to fertilizer has been slight. It will withstand considerable shade and can be propagated either by setting out plants or seeding broadcast or in rows. If planted vegetatively the plants can be set in check rows 6 to 8 feet apart and cultivated two or three times the first year. After seed begins to mature, cultivation should be stopped so that seed which shatters will sod the middle of the rows. If sown in rows 4 to 6 feet apart similar treatment should be practiced and 5 pounds of viable seed will be sufficient to plant an acre. When sown broadcast 10 to 15 pounds of viable seed are required per acre. A good seedbed should be prepared and seed sown and covered with a cultipacker or heavy log roller. This is important in obtaining a good stand. Plantings or seedings should be made in the spring in late March and April. Natural reseeding occurs during the middle to latter part of the summer and seed germinate immediately under favorable conditions. It is desirable, however, to have as near full season growth as possible so plants will be well established before cold weather arrives. Grazing should be light or controlled for the first year or two so that seed can mature and volunteer and thus thicken the sod.

It can be planted in cultivated fields as a rotation crop since it has no rootstocks and can be easily controlled. Volunteer plants from seed may appear in cultivated crops following ribbed paspalum for a short time, but they soon disappear as the seeds do not live long in the dormant stage.

Growth may start early but is slow until warm weather arrives. It will withstand fairly close grazing for short periods, but after being grazed down close, recovery is slow. On the other hand, if not grazed or cut for hay and allowed to grow in a thick stand it will smother itself and the stand will be reduced. Sufficient work has not been done on the grazing of ribbed paspalum to determine the necessary management practices for optimum production or carrying capacity. Indications are that the carrying capacity will generally be less than one animal per acre and that alternate or rotation grazing would be preferable to continuous grazing. It is very palatable either as pasture or hay and the quality of the hay is good, but the color is rather poor.

Seeds are produced in abundance, mature rapidly, shatter easily, and germinate immediately without a rest period. The seeds lose their viability rapidly, and even under favorable storage conditions the germination is reduced considerably through one winter. This weakness is a serious factor in seed distribution. The seed yields average about 100 pounds per acre at one cutting and two seed crops can be harvested a season. Harvesting may be done with binder or combine, however, either method may lower the quality because of variations in stages of maturity of seed. In some preliminary tests at

Tifton, Ga., top dressing with 200 pounds per acre of nitrate of soda in early July increased seed production about 100%.

The probable area of usefulness for *P. malacophyllum* in the United States appears to be in the lower Coastal Plain region where the winters are not too severe. Like some other warm-temperature grasses, it is susceptible to sudden freezes. In the winter of 1939–40 it completely killed out at Thorsby, Ala., and Griffin, Ga., while at Tifton, Ga., it winterkilled about 60% but quickly came back from seed which had shattered. In 1940–41 winterkilling occurred again at Thorsby, Ala., but little damage was done at Tifton, Ga.

So far, it has been resistant to diseases which have attacked other paspalum species and no major trouble has occurred with the plant or seed. Crosses have been made between this grass and other paspalums because of its disease resistant and seed-producing qualities, but the value of these hybrids has not yet been determined.—JAMES L. STEPHENS, *Coastal Plain Experiment Station, Tifton, Ga.*

BOOK REVIEWS

COMMERCIAL FERTILIZERS, THEIR SOURCES AND USE

By Gilbeart H. Collings. Philadelphia: The Blakiston Company. Ed. 3. XX + 480 pages, illus. 1941. $4.50.

ALTHOUGH the second edition of this excellent text book on commercial fertilizers was published only three years ago, the wealth of new material in this field has necessitated an almost complete revision in this new edition. Among the factors responsible are the large volume of new facts discovered dealing with primary, secondary, and rarer essential nutrient elements in the nutrition of plants; the influence of new findings on many older ideas and attitudes; and the introduction and use of new fertilizer materials such as ammonia solutions, organic nitrogen, and new synthetics. The world situation has also presented many new factors with which the American fertilizer industry has had to deal.

Special attention is paid in the new edition to plant deficiency and excess symptoms and to the adjustment of soil reaction to crops and its relation to fertilizer practice.

The arrangement and style of the book is quite similar to the previous editions. It is well typed, has a 21-page bibliography, and a good index. It should be in the hands of everyone interested in the new developments in commercial fertilizers. (R. C. C.)

FACTORS OF SOIL FORMATION, A SYSTEM OF QUANTITATIVE PEDOLOGY

By Hans Jenny. New York: McGraw-Hill Book Company, Inc. XII + 281 pages, illus. $3.50.

ACCORDING to the author of this new volume, it was written as an extension to the first part of a course on "Development and Morphology of Soils" given students at the University of California. He classifies it as an advanced treatise on theoretical soil science.

The practical soils worker in looking over the subject matter will very soon agree with the author that it is both advanced and theoretical. The fact is stressed that up to a comparatively short time ago soils were studied almost entirely from the standpoint of what we can grow on them, while today it is being more and more realized that much of ultimate practical value may result from a scientific study of the soil itself. In other words, the discovery of fundamental laws and theories may be a better way of organizing and systematizing the knowledge we have of soils than merely classifying it. The author believes that more of the methods of physics, chemistry, and mathematics should be applied to the study of soils and this "functional analysis" is what the present volume aims to present.

Besides the soil properties with which we are familiar the author also considers time, parent material, topography, climate, and organisms as soil properties or soil-forming factors and devotes a chapter to a discussion of each. He suggests a fundamental equation of soil-forming factors to the solving of which the results of experimentation, field observation, and laboratory analyses may contribute. It is impossible in a brief review even to mention the many points of interest discussed in this new and stimulating approach. Literature citations are given at the chapter ends and are quite profuse. Some soil workers may criticize some of the text as to technical or as being the result of a mathematically trained mind making more complex what is already complex. There is, however, a great deal of value outside of the mathematical treatment and every soil worker should be sympathetic toward any attempt to discover fundamental relationships within the mass of data which we already have on soils.

This attempt by an author of such training, experience, and attainments will assure the volume a place in the literature of soils. (R.C.C.)

AGRONOMIC AFFAIRS

THE PARKS' MOISTURE TESTER

ANNOUNCEMENT has recently been made by Dr. A. R. Olpin, Director of the Ohio State University Research Foundation, of the completion of licensing arrangements with the Toledo Scale Company for the manufacture and sale of the Parks' moisture tester.

This instrument, designed for the rapid determination of moisture in all forage and grain materials, was described in detail in the April, 1941, issue of the JOURNAL, and has received publicity in a large number of non-technical periodicals. The inventor, Robert Q. Parks, is a member of the staffs of the Ohio Agricultural Experiment Station and the Ohio State University.

All inquiries concerning the availability and price of this instrument should be addressed to the manufacturer, the Toledo Scale Company of Toledo, Ohio.

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THE AMOUNT AND MINERAL NUTRIENT CONTENT OF FRESHLY FALLEN LEAF LITTER IN THE HARD-WOOD FORESTS OF CENTRAL NEW YORK[1]

ROBERT F. CHANDLER, JR.[2]

THE long time that is necessary to grow a crop of trees for saw-timber and the subsequent net returns are such that man cannot afford to apply fertilizers to forest land. Therefore, the forest must to a large extent depend upon the annual accumulation of litter as a source of organic matter and essential nutrients. In view of these facts, it is rather important to know how much organic matter and nutrients are being deposited each year.

Information concerning the actual amount of annual leaf-fall in the forests of the northeastern United States is essentially lacking. Lunt (19)[3] has obtained some data on the total accumulation of forest floor in the New England states. Alway and Harmer (1) and Alway, *et al.* (3) have presented figures on the weight of the various layers of the forest floor in Minnesota. Also, Bodman (6) has presented similar data for California forests. But none of these workers have reported any values for the quantity of annual leaf-fall.

Alway and Zon (4) have shown that the pine forests of Minnesota deposit about 2,122 pounds of litter per acre per year. Kittredge (17) has shown that the chapparal communities of California deposit an average of 1,323 pounds of organic material an acre annually. Sims (21) reports that the annual deposition of litter in the pine-oak type of the southern Appalachians amounts to 2,600 to 3,100 pounds per acre.

The most exhaustive studies on this subject have been conducted in Europe. Ebermayer (11) gives the results of many years of study on the amount and composition of leaf litter deposited in the forests of central Europe. His values for the amount of dry matter in the annual litter-fall of mixed hardwood forests, composed principally of European beech with an admixture of oak and birch, ranged from

[1]Contribution from the Department of Agronomy, Cornell University, Ithaca, N. Y. Received for publication May 13, 1941.

[2]Associate Professor of Forest Soils. The chemical analyses were made by T. H. Eaton, Jr.

[3]Figures in parenthesis refer to "Literature Cited", p. 871.

2,300 pounds to 5,000 pounds per acre with an average of approximately 3,132 pounds.[4]

Since all of the data on the total amount of dry matter deposited annually by forest trees have been secured in regions other than the northeastern United States, a study was undertaken in the fall of 1940 to determine the actual amount and mineral nutrient content of the leaf material on various soil types in central New York.

EXPERIMENTAL PROCEDURE

SELECTION OF SAMPLING AREAS

All areas had closed stands of mixed, second-growth hardwoods with the dominant trees ranging from 30 to 70 years of age. This spread in age seemed permissible since Ebermayer (11) showed that 30- to 60-year-old hardwood stands in Germany desposited 3,200 pounds of litter per acre, whereas stands of the same species that were from 60 to 90 years old deposited 3,130 pounds per acre. Thus, age of stand did not prove to be an important factor in influencing the amount of litter-fall.

The soil types were selected so as to have both productive and unproductive soils represented. The more productive soils as judged from results obtained with agricultural crops were Ontario loam, Lansing silt loam, and Dunkirk silt loam. Lordstown stony silt loam was selected as a less productive soil type. The humus layer type on the Ontario, Dunkirk, and Lansing soils was a coarse mull (13), exhibiting relatively rapid disintegration and incorporation of the litter. The humus layer type on the Lordstown soil was a matted mor, with a well-developed H-layer on top of the mineral soil. Further information on these soil types may be found in the descriptive material compiled by Howe (15).

METHOD OF OBTAINING LEAF-LITTER SAMPLES

A square, heavy-wire frame was constructed so that the area within the square was 0.00025 acre (approximately 3.33 feet on a side). After the general area was selected on the basis of stand and soil characteristics, this square was placed on the ground, being careful not to place it in either a depression or on the top of a hummock or knoll. Then all the freshly-fallen leaves were picked from the area and placed in a cloth bag. The samples were next taken to the laboratory, dried at a temperature of about 70° C, and weighed.

All samples were collected as soon as leaf-fall was essentially complete. A few oak trees still retained a small portion of their leaves, but to avoid further decomposition of the litter that had already fallen, the samples were obtained without the inclusion of these leaves. All samples were obtained between October 18 and November 15. The reason for the spread in sampling period was because the trees on the Ontario and Lansing soils shed their leaves at a later date than those on the Dunkirk and Lordstown soils. Twenty-four individual 0.00025-acre samples were obtained from the less productive Lordstown soil and 26 samples from the more-productive Ontario, Lansing, and Dunkirk soils. The tree species encountered in these studies are listed in Table 1.

[4]These values were presented on an air-dry basis and have been corrected, assuming a moisture content of 13%.

TABLE 1.—*List of common and scientific names of tree species encountered in this study.*

Common name	Scientific name
American elm	*Ulmus americana* L.
Aspen	*Populus tremuloides* Michx. and *P. grandidentata* Michx.
Basswood	*Tilia americana* L.
Beech	*Fagus grandifolia* Ehrh.
Bitternut hickory	*Hicoria cordiformis* (Wang.) Britt
Black birch	*Betula lenta* L.
Black cherry	*Prunus serotina* Ehrh.
Cucumber tree	*Magnolia acuminata* L.
Hop hornbeam	*Ostrya Virginiana* (Mill.) Koch.
Red maple	*Acer rubrum* L.
Red oak	*Quercus borealis* var. *maxima* (March) Ashe
Sweet cherry	*Prunus avium* L.
Sugar maple	*Acer saccharum* Marsh
Tulip poplar	*Liriodendron tulipifera* L.
White ash	*Fraxinus americana* L.
White oak	*Quercus alba* L.

Soil samples of the surface layers were obtained from each area and were taken to the laboratory for pH determinations.

The height and age of a few representative dominant trees were obtained on each area, so as to calculate the approximate mean site-index value for the woodlot.

The diameters of all trees included within the area where the litter samples were obtained, were measured. The data were converted to basal area and the abundance of each species was expressed as a percentage of the total. This was done so as to obtain an estimate of the relative proportion of the leaf litter that was contributed by the various species.

METHODS OF CHEMICAL ANALYSIS

After drying, the leaves from each sampling area were thoroughly mixed together. A representative sub-sample was removed and saved for chemical analysis. The leaves of the various tree species were then separated from the remainder of the sample so as to determine what differences in chemical composition occurred between species. The samples were ground in a hammer mill so that all of the material would pass through a 50-mesh sieve. The chemical determinations were made on a representative sub-sample of this ground material.

Total nitrogen was determined by the micro-kjeldahl method modified so as to include nitrate nitrogen.

For the calcium and magnesium determinations, the sample was ashed in the muffle furnace and taken up with HCl. After the removal of silica and iron, calcium was determined on the leachate by the usual ammonium oxalate precipitation procedure. After filtering the precipitate, the oxalate was titrated with $KMnO_4$ solution.

Magnesium was determined on the filtrate from the calcium determination by precipitation with 8-hydroxyquinoline in ammoniacal solution.

In determining phosphorus and potassium, the organic matter was destroyed by treating the sample with nitric acid followed by 70 to 72% perchloric acid. The material was digested on a hot plate until colorless. After filtering, the

phosphorus content of the clear solution was determined by the Fiske and Subbarow method (10).

Potassium was determined on an aliquot of the same filtrate by the method of Hibbard and Stout (14).

The pH of the soil samples was determined potentiometrically using a glass electrode.

EXPERIMENTAL RESULTS

THE AMOUNT OF FRESHLY FALLEN LEAF LITTER

The soil type, site index of the dominant trees, number of individual samples obtained, and the amount of freshly fallen leaf litter are given in Table 2.

TABLE 2.—*Soil type, number of samples, site index of the dominant trees, and the amount of freshly fallen leaf litter on the various areas.*

Soil type	Approximate* site index of dominant trees	Number of individual samples obtained	Amount of freshly fallen leaf litter, lbs. per acre	Average amount of litter for each soil type, lbs. per acre
Ontario loam (I)	65	6	3,020±83.4	2,933±33.7
Ontario loam (II)	65	6	2,847±56.0	
Dunkirk silt loam	70	8	2,736±99.8	2,736±99.8
Lansing silt loam	62	6	2,624±91.8	2,624±91.8
Lordstown stony silt loam (I)	49	6	2,590±64.8	
Lordstown stony silt loam (II)	47	6	2,698±35.2	2,571±16.9
Lordstown stony silt loam (III)	50	12	2,425±53.2	

*Site index is the height in feet at 50 years of age. The values were estimated from the data for oak presented by Schnur (20).

An inspection of this table reveals that the total amount of litter deposited on the different areas did not show extreme variation. The smallest amount of 2,425 pounds was on one of the Lordstown stony silt loam areas. This particular site had a shallow soil, not averaging over 18 inches in depth. The highest values were obtained from the Ontario loam. The standard errors of the mean were calculated and generally proved to be rather high. On the basis of the data presented here, the only differences that were statistically significant (more than twice as great as the standard error of the difference) were those existing between the Lordstown and Ontario soil areas. This held true whether comparing the individual areas or the averages for each soil type.

If, however, all of the "productive" soils are averaged and compared with the mean for the "unproductive" soils, we find that the difference is statistically significant, the more productive soils averaging 2,807 pounds per acre and the less productive 2,571 pounds. In spite of this statistical significance it should be emphasized that the actual difference is not large (236 pounds). One, therefore, should not expect large differences in amount of litter-fall due to differences in site quality. This would seem true, at least, for differences in site quality of similar magnitude to those included within this study.

MINERAL NUTRIENT CONTENT OF LITTER OF INDIVIDUAL TREE SPECIES

The nitrogen, phosphorus, potassium, calcium, and magnesium contents of the litter of the different tree species were determined separately for the trees growing on each soil type. To simplify the presentation, however, only the average data for the Ontario, Dunkirk, and Lansing soils, on the one hand, and for the Lordstown soils, on the other hand, are presented in Table 3.

TABLE 3.—*The nitrogen, phosphorus, potassium, calcium, and magnesium contents of the freshly fallen leaf litter of the various species on the two groups of soils.*

Tree species*	Nitrogen content, %		Phosphorus content, %		Potassium content, %		Calcium content, %		Magnesium content, %	
	P†	U†	P	U	P	U	P	U	P	U
Basswood	1.04	1.14	0.14	0.17	0.39	0.66	3.24	3.22	0.39	0.28
Tulip poplar	0.51	—	0.11	—	0.95	—	2.56	—	0.45	—
Bitternut hickory	0.68	0.67	0.10	0.13	0.45	0.43	3.41	3.41	0.50	0.60
Aspen	0.70	0.77	0.08	0.12	0.36	0.58	1.85	2.37	0.23	0.23
Hop hornbeam	1.01	1.04	0.09	0.11	0.35	0.50	2.52	2.15	0.35	0.23
White ash	0.59	0.67	0.15	0.16	0.46	0.62	2.28	2.46	0.29	0.25
Black cherry	0.55	0.64	0.18	0.18	0.47	0.64	2.58	2.15	0.44	0.41
American elm	0.77	—	0.15	—	0.44	—	2.06	—	0.32	—
Sweet cherry	0.88	—	0.15	—	0.63	—	2.42	—	0.57	—
Sugar maple	0.43	0.45	0.12	0.15	0.45	0.58	1.65	1.68	0.28	0.19
Black birch	—	0.72	—	0.17	—	0.75	—	1.65	—	0.30
Cucumber tree	0.59	0.57	0.28	0.29	0.81	0.71	1.62	1.80	0.30	0.28
Red maple	0.41	0.44	0.11	0.11	0.30	0.49	1.35	1.17	0.32	0.21
Red oak	0.67	0.57	0.11	0.11	0.55	0.76	1.49	1.28	0.31	0.21
White oak	0.50	0.58	0.12	0.14	0.52	0.52	1.22	1.51	0.24	0.24
Beech	0.59	0.69	0.10	0.10	0.65	0.65	1.09	0.99	0.26	0.18
Av. value for all species	0.65	0.69	0.13	0.15	0.46	0.60	2.01	2.02	0.33	0.28
Student's "Z" value	0.56		0.95		1.57		0.11		0.83	
Odds that difference is not due to chance alone common to both groups of soil types	13:1		102:1		1,999:1		1.6:1		50:1	

*A list of corresponding scientific names of the various tree species is given in Table 1.
†The figures under "P" were obtained by averaging the data for the more productive Ontario, Dunkirk, and Lansing soils, while the values under "U" were obtained by averaging the data for the less productive Lordstown soils.

The nitrogen content of the litter was not significantly different on the two groups of soil when average values were compared for those species that were common to both groups of soil. Basswood, hop hornbeam, and aspen proved to have the highest nitrogen content, averaging from 0.70 to 1.14% nitrogen. Sugar maple and red

maple, on the other hand, were consistently low in total nitrogen, containing not more than 0.45%. All other species that were common to both soil groups ranged from 0.50 to 0.69% nitrogen. It should be mentioned that of the species that occurred on only one of the soil groups, American elm, sweet cherry, and black birch were relatively high in nitrogen content, while tulip popular was low.

The leaf litter of the trees growing on the more acid Lordstown soils had a significantly higher phosphorus content than the litter from the trees on the more productive Ontario, Dunkirk, and Lansing soils. Using Student's "Z" test (18), the odds were 102:1 that the difference was not due to chance alone. The actual difference, however, was small. Among the species common to both soil groups, the cucumber tree, black cherry, basswood, and white ash had the highest phosphorus contents, while aspen, hop hornbeam, beech, red maple, and red oak were rather low in this respect. The cucumber tree was the outstanding species in that its leaf litter contained over 0.10% more phosphorus than the litter of any other species.

The potassium content of the leaf litter from the trees growing on the less productive soils was higher than that of the trees growing on the better soils. The difference was considerable, averaging 0.46% for the good soils and 0.60% for the poor ones. When the trees were ranked in order of decreasing potassium content, the two groups did not agree very well. It can be stated, however, that the cucumber tree, red oak, black cherry, and white ash tend to have rather high potassium contents in their leaf litter, while red maple and hop hornbeam are low. Contradictory results were obtained with white oak, basswood, aspen, and bitternut hickory. Of the species not common to both soil groups, tulip popular, sweet cherry, and black birch were high in potassium.

There was no difference in the average calcium content of the leaf litter from the two soil groups. Those species that were high in calcium content of litter are bitternut hickory, basswood, black cherry, tulip popular, hop hornbeam, white ash, and aspen. Those species that were particularly low in calcium content are beech, white oak, red oak, and red maple.

The calcium content showed greater variation among species and the total amount present was larger than that of any other element studied.

The magnesium content of the leaf litter from the Lordstown soils was significantly lower than that from the Ontario, Dunkirk, and Lansing soils. The actual difference was only 0.05%. This probably would not be of great importance from the standpoint of the maintenance of soil fertility. Among those species that were present on both soil groups, the highest magnesium content was found in the leaf litter from bitternut hickory, black cherry, basswood, and cucumber tree. The lowest magnesium content occurred in beech, white oak, aspen, and sugar maple. Sweet cherry and tulip poplar also proved to have high magnesium contents when growing on the better soils.

The mineral nutrient contents of the litter of the different species agrees fairly well with data presented in the literature. Unfortunately, there are relatively few data for freshly fallen leaf litter of the north-

eastern tree species. Plice (16) presents considerable data for the calcium content of leaves, and he also gives some average data for the nitrogen content as determined by other workers. The nitrogen contents reported were generally higher than those presented in this paper; but of the species common to both workers the same general order obtained, that is, elm was in the higher group, the oaks, hickories, and beech were medium, and the maples were low. The calcium contents of freshly fallen leaves as given by Plice (16) agree very well with the analyses reported here. These results indicate that the calcium content of foliage is largely determined by the tree species rather than by the site on which the trees are growing.

Alway, Maki, and Methley (2) reported on the calcium, magnesium, phosphorus, and nitrogen contents of freshly fallen leaves in Minnesota. In considering their results it should be remembered that they sampled leaves from shade trees on the University campus rather than trees growing in natural forest stands. There is considerable agreement, however, between their results and those reported here. In the case of nitrogen, basswood and elm proved to be the highest and soft maple the lowest. Their results for phosphorus did not seem to agree very closely with our results, although there were not many species that were common to both studies. Calcium, on the other hand, agreed quite well, basswood and elm being high with the oaks and maples only medium. Magnesium also showed a rather high correlation between the two sets of data. Basswood was high, while the oaks and maples were rather low.

The results obtained by Coile (10) showed a good agreement with the results obtained in this study with respect to the nitrogen and calcium contents of the litter. Unfortunately, however, there were only three species common to both studies.

FACTORS DETERMINING ACTUAL NUTRIENT CONTENT OF LITTER

The data in Table 3 indicate that the average composition of the leaf litter falling on a given area is determined more by the species composition of the stand than by any difference in the chemical composition of the leaves of any species as influenced by the character of the soil. If this is true, one should be able to calculate the average composition of the litter if he knows the mineral nutrient content of the litter of the individual species and the proportionate amount of the litter that is contributed by the various species of trees. In order to check these relationships, the assumption was made that the basal area (cross-sectional area of the trunk at breast height) of a species is roughly proportional to its crown-size. Therefore, the basal area of each species was expressed as percentage of the total basal area. These figures should give an idea as to the relative proportion of the leaf litter deposited by each species. These data are presented in Table 4, as averages for the four soil types.

One can see that the species composition on the various soil types varied considerably. The Lansing soil proved to have a high proportion of basswood, red oak, and bitternut hickory; the Dunkirk soil was very high in basswood, while the Lordstown soil had a high pro-

TABLE 4.—*Species composition of the stands on the different soil types expressed as percentage of the total basal area.*

Tree species	Ontario loam	Dunkirk silt loam	Lansing silt loam	Lordstown stony silt loam
Basswood	17.97	57.12	31.48	1.00
Sugar maple	35.13	8.54	1.47	37.68
Red oak	—	11.73	26.91	25.71
Red maple	—	3.70	—	7.03
Bitternut hickory	0.62	—	23.55	2.24
White ash	9.74	7.00	7.31	2.98
Black cherry	2.73	2.79	6.17	—
Black birch	—	—	—	3.22
White oak	—	—	—	7.68
Beech	14.63	—	—	12.46
Cucumber tree	—	3.40	—	—
Tulip poplar	2.01	5.72	—	—
American elm	17.17	—	3.11	—

portion of sugar maple, red oak, and beech, with very few basswood trees. The Ontario soil had a high proportion of sugar maple and a moderate amount of basswood and beech. Other tree species are present on all plots but because their basal area percentages were less than 1, they were not listed in the table.

The actual mineral nutrient content of the leaf litter of each species on each plot is known. Therefore, if a weighted average is calculated in accordance with the percentage of each species present, one should obtain an average value which approximates the actual mineral nutrient content of a composite sample of leaf litter as it occurred on the area.

In Table 5, the mineral nutrient contents of the litter calculated by this procedure are listed. In addition, data are presented for the actual mineral nutrient content of the litter as determined in the laboratory on a mixed composite sample of litter.

TABLE 5.—*The actual mineral nutrient content of the leaf litter on the various soil types as compared with the calculated mineral nutrient content based on the relative proportion of the various trees present on the plots.*

Soil type	Nitrogen, %		Phosphorus, %		Potassium, %		Calcium, %		Magnesium, %		pH of the surface 3 inches of mineral soil
	A*	C*	A	C	A	C	A	C	A	C	
Ontario loam	0.54	0.58	0.11	0.11	0.30	0.32	2.34	2.20	0.37	0.36	5.90
Dunkirk silt loam	0.60	0.73	0.16	0.14	0.73	0.60	2.67	2.63	0.34	0.31	6.75
Lansing silt loam	0.77	0.75	0.11	0.10	0.52	0.61	2.97	2.64	0.43	0.39	6.76
Lordstown stony silt loam	0.55	0.55	0.11	0.13	0.46	0.64	1.66	1.52	0.21	0.20	4.53
Mean values	0.62	0.65	0.12	0.12	0.50	0.54	2.41	2.25	0.34	0.32	

*A = Actual value as determined by chemical analysis of the composite litter sample; C = Calculated value as determined by weighting the actual value for each species in accordance with the percentage basal area figures for the various tree species present.

In general, the actual analyses and calculated values agree rather well. The greatest discrepancy occurs in the case of the potassium content of the litter from the Dunkirk, Lansing, and Lordstown soils. This is apparently because the potassium content of the leaf litter is not as specific for a given species as is the content of other nutrients. (See Table 3.)

When the mean values for the actual and calculated data are compared very good agreement is noted. The general statement can be made that if the proportion of the various tree species is known, then with a knowledge of the nutrient content of the litter of the individual trees, a reliable estimate of the average nutrient content of the litter can be made.

RELATIONSHIPS BETWEEN MINERAL NUTRIENT CONTENT OF LITTER AND pH OF SOIL

It is of interest to determine if any relationship exists between the potassium, calcium, and magnesium contents of the litter and the pH of the surface 3 inches of soil.[5] The pH data are recorded in the last column of Table 5. An examination of the figures reveals that there was not a definite relationship between the pH of the surface soil and the potassium and magnesium contents of the litter, based on actual analysis, although there was a tendency toward higher potassium and magnesium contents on the Lansing and Dunkirk soils that had the highest pH values. The calcium analyses, on the other hand, were very definitely correlated with soil pH. In order to show the relationship clearly, the results for the seven individual plots are presented in Fig. 1.

In view of both the actual amounts present, as well as the replacing activity of the cations concerned, one would expect a closer relationship between calcium and pH of the soil than with either potassium or magnesium. Auten (5) has demonstrated the presence of a high concentration of calcium in the surface layers of forest soils, but his results indicated that only small amounts of magnesium were accumulated.

The data presented in Table 3 show that this relationship is not caused by an increased absorption of calcium by a given species on the soils with a higher pH. The cause, as indicated in Tables 4 and 5, is related to the fact that the soils with a higher pH have a larger proportion of high-calcium-absorbing trees growing on them. In addition, these high-calcium trees tend to maintain greater pH values in the surface soil as evidenced by the work of Chandler (7, 8), Coile (9), and others. Bodman (6) has shown a much higher accumulation of calcium under fir forests than under pine in California.

It may seem strange that pH values ranging from 4.5 to 6.7 do not produce differences in the calcium content of the litter of a given species. The writer has been interested in this problem for several years and during the fall of 1938 leaf samples were collected from 11 different species on highly calcareous soils (Honeoye and Farmington silt loams with a pH of the surface soil of 7 or more). The same 11

[5]The samples were the A_2 horizon of the Lordstown soils and the A_1 horizon of the other soil types.

species were sampled from acid soils (Lordstown and Volusia stony silt loams with pH values ranging from 4.5 to 5.0). The calcium content of the foliage did not show any consistent differences on the two groups of soil, the mean value for the calcareous soils being 2.09 and the corresponding value for the acid soils being 2.03. The question then arose as to whether any soil is acid enough to depress the calcium content of the foliage. In order to obtain light on this point, sugar maple leaves were collected in September 1939 from trees growing on extremely acid, as well as less acid soils, in the Adirondacks. Samples were also collected from the same species on the moderately acid to neutral soils of central New York.

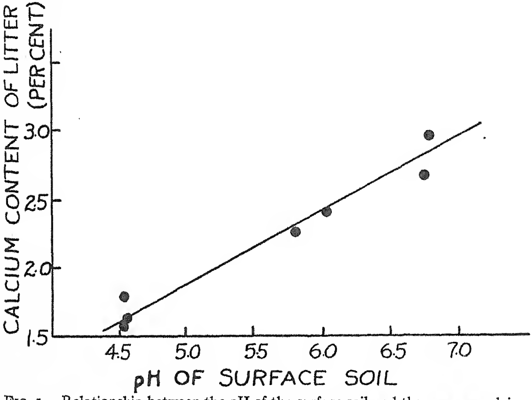

FIG. 1.—Relationship between the pH of the surface soil and the average calcium content of the litter on different sites.

The mature leaf material was collected from at least 10 trees on each soil. The results are presented graphically in Fig. 2. An inspection of this graph shows that the acid soils of the Adirondack region (spruce-hardwood type) produce sugar maple trees which have a below-normal calcium content. Since sugar maple trees cease to exist or, at least, become very scarce on extremely acid soils, it may be that calcium is actually a growth-limiting factor under these conditions. It was very difficult to find enough trees to constitute a sample on the most acid soils.[6]

[6]The pH values refer to the surface 3 inches of soil and in the case of the two most acid soils, the samples consisted of H-layer material from the mor humus layer. The H-layer was selected in the latter cases because most of the feeding roots were in this layer. The pH and percentage base saturation of the upper mineral soil (A_2 horizon) were similar to those of the H-layer and hence their use would not have altered the relationship.

The data indicate that pH values below about 4.5 may constitute conditions which are unfavorable for maximum absorption and accumulation of calcium. But pH values higher than this do not cause increased absorption of the element. In terms of percentage base saturation, values below about 30% seem to be critical, while variations above this point apparently have no effects on the calcium content of the foliage.

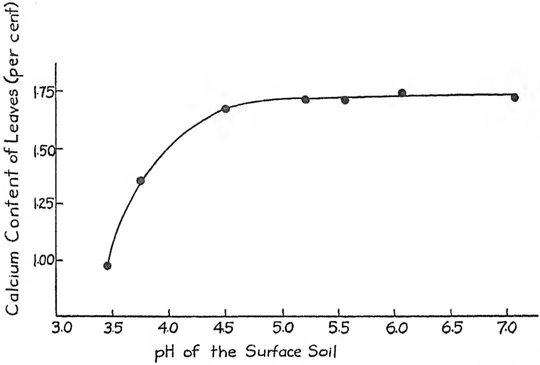

FIG. 2.—Relationship between the pH of the surface soil and the average calcium content of sugar maple leaves on different sites.

AMOUNT OF VARIOUS NUTRIENTS RETURNED TO SOIL

After knowing the amount of dry matter deposited on an acre of land (Table 2) and after having determined its mineral nutrient content (Table 5), it is a simple matter to calculate the actual amount of a mineral nutrient returned to the soil at the time of leaf fall. These amounts are presented in Table 6. The litter from the Ontario, Dunkirk, and Lansing soils, in general, returned more nutrients than that

TABLE 6.—*The amounts of the different nutrient elements returned to the soil by forest tree leaf litter on the various soil types.*

Soil type	Nutrient elements, pounds per acre				
	N	P	K	Ca	Mg
Ontario loam	15.8	3.2	8.8	68.7	10.9
Dunkirk silt loam	16.4	4.4	20.0	73.0	9.3
Lansing silt loam	20.2	2.9	13.6	78.0	11.3
Lordstown stony silt loam	14.2	2.8	11.8	42.7	5.4
Average values	16.6	3.3	13.5	65.6	9.2

from the Lordstown soils. An exception is the amount of potassium returned to the Ontario loam soil. The percentage potassium content of the litter was consistently low on this soil type and the larger amount of litter produced was not sufficient to overcome it.

The general statement can be made that liberal amounts of nitrogen and calcium were returned, while potassium and magnesium were considerably lower. The amounts of phosphorus were particularly low.

SUMMARY AND CONCLUSIONS

The amount of dry matter deposited annually by hardwood forest tree leaf litter in closed, second-growth stands in central New York ranged from 2,425 to 3,020 pounds per acre.

The more productive soils judged from agricultural crop yields tended to produce somewhat more leaf litter. The differences were not large, however, the maximum between the lowest and highest soil type being only 236 pounds per acre.

The nitrogen and calcium content of the leaves on a percentage basis was not significantly different on the more productive and less productive soil types. The magnesium content was higher, while the phosphorus and potassium contents were lower on the more productive soils.

Species whose leaf litter was high in nitrogen content are basswood, hop hornbeam, aspen, American elm, sweet cherry, and black birch. Sugar maple and red maple had a low nitrogen content.

The highest phosphorus content was exhibited by cucumber tree, black cherry, basswood, and white ash, while aspen, hop hornbeam, beech, red maple, and red oak were rather low in this respect.

The potassium content of the leaf litter was the least consistent by species, the content apparently being determined more by soil type. However, tulip poplar, sweet cherry, cucumber tree, black cherry, and red oak seemed to be rather high in potassium content.

The calcium content of the litter was high in the case of the bitternut hickory, basswood, black cherry, tulip poplar, white ash, and aspen. The lowest calcium content was found in beech, white oak, red oak, and red maple.

The magnesium content proved to be highest in the case of bitternut hickory, basswood, black cherry, and tulip popular. The lowest magnesium contents occurred in beech, white oak, aspen, and sugar maple.

Some rather distinct differences in species composition existed on the various soil types. The more calcareous and fertile Ontario, Dunkirk, and Lansing soils were higher in the proportion of basswood present, while the acid Lordstown soils had very large amounts of sugar maple, red oak, and beech with few basswood.

The differences in the average mineral nutrient content of the leaf litter falling on a given area were caused more by the inherent differences in the normal nutrient content of the litter of the various individual species than by the influence of the soil type upon the mineral nutrient content of a given species. Potassium proved to be a partial exception to this statement.

The average calcium content of the litter was closely correlated with the pH of the surface soil. This, again, was caused by differences in proportion of tree species present rather than by any one species absorbing more calcium on the high-calcium soils.

It was demonstrated in the case of the sugar maple, however, that if the pH of the surface soil is below 4.5, there may be a direct relationship between soil pH and calcium content of foliage.

The actual amount of the essential nutrients returned to the soil was calculated. The average figures expressed as pounds per acre of the elements are as follows: Nitrogen, 16.6 pounds; phosphorus, 3.3 pounds; potassium, 13.5 pounds; calcium, 65.6 pounds; and magnesium, 9.2 pounds.

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NEW RED OATS FOR FALL SEEDING RESISTANT TO RUSTS AND SMUTS[1]

F. A. Coffman, H. B. Humphrey, and H. C. Murphy[2]

The introduction of Victoria and Bond into the United States, the discovery of their crown rust resistance (5, 10),[3] and the recently demonstrated role of stem rust in the South have materially changed the objectives and course of breeding oats in most parts of the United States. Progress in breeding early oats for spring seeding, resistant to these diseases, has been discussed in previous papers (2, 4, 5, 6, 11, 12, 13); also, the successful attempts to introduce crown rust and smut resistance into the so-called common (*Avena sativa*) winter oats varieties Lee and Hairy Culberson (7). These latter, together with certain crosses between leading varieties of red oats with Victoria in 1930 and with Bond in 1932, promised a solution of this problem, but, no sooner had crown-rust-resistant segregates become available for testing than it became evident that resistance to stem rust also is necessary for the above-named section. The role of stem rust in the South, although apparently less important in some sections than that of crown rust, had not been fully realized prior to 1932. It is now clear that oats are needed which are resistant to both rusts, as well as to cold and to smut. The present paper indicates the progress made in attaining these objectives.

MATERIALS AND METHODS

The resistance of Victoria to crown rust was first observed by Murphy (5) at Manhattan, Kans., in June, 1929. It was then too late to make crosses at Manhattan; but, promptly utilizing the information gained, crosses were made with Red Rustproof at Aberdeen, Idaho, 10 days later, and with numerous other varieties in the greenhouse at Arlington Farm, and at Ames, Iowa, during the following winter. Unfortunately, at the time these first crosses were made, it was not known that Victoria was impure for crown rust resistance. All segregates of the cross made at Aberdeen in 1929 proved susceptible. Because of this, the value of Victoria as a source of crown-rust resistance was not universally recognized. A second major setback occurred with the destruction by birds of all F_1 plants from Victoria crosses made at Ames in 1930. Hence, data on selections resulting only from the crosses made in 1930 at Arlington are presented in this paper.

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[2]Agronomist, Principal Pathologist, and Pathologist, respectively, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture. Credit is due T. R. Stanton for assistance and suggestions in conducting these experiments; to Harland Stevens of Aberdeen, Idaho, who assisted in making crosses and in growing early generation plants; and to John W. Taylor, Arlington, Va.; H. S. Garrison, Tifton, Ga., C. Roy Adair, Stuttgart, Ark., I. M. Atkins, Denton, Tex., and A. T. Bartel, Tucson, Ariz., all members of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and to Proctor W. Gull, Agronomist, Delta Branch Station, Stoneville, Miss., for assistance in some of the breeding phases; and to workers at several other experiment stations who cooperated in the cold-resistant studies.

[3]Reference by number is to "Literature Cited", p. 882.

The resistance of Bond to crown rust was first discovered in 1931 (10). Bond, like Victoria, has been employed extensively in crossing with both winter and spring oat varieties. It is even more resistant to most races of crown rust than is Victoria, but its susceptibility to several races of smut that attack red oats, together with its prominent basal scar or "suckermouth", which is transmitted to many progeny, has proved so detrimental that, although many segregates from crosses of Bond on winter oat varieties have been tested, nearly all of them have been discarded. Hence, no data for Bond crosses are reported herein.

Richland, Rainbow, Iogold, Anthony, and several other varieties have proved excellent parents in crossing to produce stem-rust-resistant spring oats (2, 4, 6, 11, 12). In the present study, segregates of the Victoria-Richland cross (11) were used to secure stem-rust, crown-rust, and smut resistance.

Early generations of the crosses have been grown mostly in the greenhouse at Arlington, Va., and in the fields at Aberdeen, Idaho, Tucson, Ariz., and Ames, Iowa. The facilities of the Aberdeen and Tucson stations, because of favorable conditions for growth, including absence of disease, have made it possible to secure large yields of grain and a rapid increase of desirable strains. Winter oats can be seeded in the fall at Tucson with no danger of loss from winterkilling, and, if seeded early, will mature satisfactorily from spring seeding at Aberdeen. Plantings in the greenhouse at Ames and Arlington and in the field at Ames have been utilized especially to determine reaction to crown and stem rusts and smut. The use of greenhouses in conjunction with the field stations has also permitted growing two generations per year, and thus greatly speeded up the breeding program. Later generations have been grown at a number of stations in the southern United States, where determinations of winterkilling, yield, lodging, time of maturity, character of grain, and other characters of practical importance have been made.

Methods of inoculation and testing for the various diseases were the same as those described in previous studies (2, 4, 6, 7, 11, 12, 13).

Although Victoria, Bond, and the rust-resistant Victoria-Richland segregates have been crossed with a number of red oats, only the results of crosses of Nortex ×Victoria, Fulghum×Victoria, Red Rustproof×Victoria-Richland, and backcrosses of the latter, are here discussed at length.

CROSSES OF VICTORIA WITH NORTEX AND FULGHUM

Victoria was crossed with Nortex and Fulghum in the winter of 1929–30, and the F_1 plants were grown at Aberdeen, Idaho, in 1930 (3). Early generations were grown in the greenhouse at Arlington Experiment Farm, Arlington, Va., where they were subjected to artificially-induced epidemics of smut and crown rust, and also seeded in the field to determine their relative winter hardiness and various characteristics bearing upon their possible agronomic value. At various times from 1930 to 1940, bulked seed of the crosses and seed of various selections were sent to cooperating stations throughout the southern states, including Experiment and Tifton, Ga., Stuttgart, Ark., Baton Rouge and Calhoun, La., College Station and Denton, Tex., Statesville, N. Car., Quincy and Gainesville, Fla., Stoneville, Miss., Tucson, Ariz., and Davis, Calif. Many of the spring-type segregates also were sent to Ames, Iowa, Manhattan, Kans., Lincoln, Nebr., and Columbus, Ohio, for spring seeding.

Because numerous red oat selections having resistance to both stem and crown rusts are now available for spring seeding, the results of this earlier selection work are no longer of special interest and are not considered here. Many selections have been made by the cooperators at these stations in addition to those made by the writers at Arlington Farm and elsewhere. Altogether, several thousand selections have been tested in the greenhouse and in field tests at Arlington Farm and the cooperating stations. In the course of this work, all selections showing susceptibility to crown rust or smut were eliminated. Many, also, were discarded because they lacked winterhardiness, produced poor yields, or were agronomically undesirable. Consequently, only a comparatively few strains remain. The relative winter hardiness and yields of the more promising of these, as compared with the hardy red oat Appler are presented in Table 1.

These strains have thus far been resistant to the races of crown rust and smut commonly observed in the South, and consequently no data for these diseases are included in Table 1. It is realized that the selections may lack complete protection to all known races of these diseases, yet the resistance obtained should give ample protection under field conditions to the races attacking the crop in that section.

It will be noted that all of the selections approach or exceed Appler in winterhardiness. The red oat parents (Nortex and Fulghum) were included in the winterhardiness tests. In 185 comparable tests in the uniform winterhardiness nurseries, the winter survival of Appler exceeded that of Nortex by 2.4%. Hence, it may be assumed that such selections as Rangler and the unnamed selections C. I. Nos. 3740 and 3741[4] are as hardy as the hardy parent. Appler apparently is more winterhardy than Fulghum (C. I. 708) (1); hence, it may be assumed that some of the Fulghum×Victoria selections are at least as hardy as Fulghum. One of the latter, Fultex, appears to be even more winterhardy than Appler and, consequently, more winterhardy than the Fulghum parent.

Most of the selections also approach or exceed Appler in yield as determined by yield tests at Arlington Farm in 1939 and in six nurseries at various locations in 1940. Since rust was not a limiting factor in these tests, these data may be regarded as conservative estimates of comparative yields in areas where crown rust generally prevails.

Some of these selections, it will be noted, have been named (9) and some also have been released for distribution to farmers. Among the more promising are Ranger (C. I. 3417) and Rustler (C. I. 3754) selected by P. C. Mangelsdorf and E. S. McFadden at College Station, Tex., and Fultex[5] (C. I. 3531) selected by I. M. Atkins and P. B. Dunkle at Texas Substation No. 6, Denton, Tex. Other promising selections also have been produced at these stations, as well as at other stations.

Ranger and Rustler are being increased for possible distribution, especially in southern Texas, and Fultex around Denton and else-

[4]C. I. refers to accession number of the Division of Cereal Crops and Diseases.

[5]ATKINS, I. M., and DUNKLE, P. B. Report of oat variety tests. Tex. Agr. Exp. Sta. 672 Progress Rpt. April 19, 1940. [Mimeographed.]

where in the northern part of the state. In plot experiments (9), these new varieties have yielded only slightly less than the best-adapted Red Rustproof strains in years when crown rust was not a factor. When rust has been severe, they have outyielded such varieties by as much as 15 to 30 bushels per acre in comparable tests.

TABLE 1.—*Comparative winter survival and yields of crown-rust and smut-resistant selections from the crosses Nortex × Victoria and Fulghum × Victoria.*

C. I. No.	Variety	Station where selected	Winter survival: Station years compared	Winter survival: Average %	Winter survival: Comparable average of Appler, %	Winter survival: % of Appler	Average yield, bu. per acre: 1939*	Average yield, bu. per acre: 1940†
			Nortex × Victoria					
3417	Ranger	College Station, Tex.	45	61.7‡	65.5	94.2	68.7	90.4
3525		Aberdeen, Idaho	35	51.8‡	56.9	91.0	48.8	74.0
3526		Aberdeen, Idaho	44	64.3‡	66.0	97.4	59.6	78.7
3534		Denton, Tex.	5	75.0	79.0	94.7	65.8	87.4
3733	Rangler	Arlington, Va.	21	63.9‡	63.3	100.9	67.2	102.9
3740		Aberdeen, Idaho	5	82.0	77.0	106.5	69.0	69.7
3741		Aberdeen, Idaho	5	77.0	77.0	100.0	68.8	85.8
3754	Rustler	College Station, Tex.	21	62.0‡	63.3	97.9	§	§
			Fulghum × Victoria					
3528		Denton, Tex.	5	76.0	77.0	98.7	66.6	85.6
3530		Denton, Tex.	5	57.0	77.0	74.0	52.5	51.0
3531	Fultex	Denton, Tex.	50	67.7‡	61.1	110.8	70.2	91.5
3532		Denton, Tex.	5	55.0	77.0	71.4	47.4	64.6
			Check					
1815	Appler						64.4	98.7

*Yields from rod-row nursery at Arlington, Va.
†Average yield from six nurseries, two located at Arlington, Va., and one each at Stoneville Miss., Stuttgart, Ark., Denton, Tex., and Tuscon, Ariz.
‡Data from mimeographed reports on cooperative winterhardiness nurseries conducted in 1938–39, 1939–40, and 1940–41.
§Not grown in comparable yield tests.

Unfortunately, Rustler (C. I. 3754) was not included in the yield tests on which data are presented in Table 1. Available data on the variety indicate, however, that it does not equal Ranger (C. I. 3417) in yield. In tests (9) conducted for the 5-year period 1936–40, at College Station, Tex., the average yields of Ranger, Rustler, and Nortex (C. I. 2382) were 48.5, 40.4, and 37.0 bushels, respectively.

RED RUSTPROOF×VICTORIA-RICHLAND CROSSES

In the attempt to produce a stem-rust, crown-rust, and smut-resistant winterhardy variety, typical strains of Red Rustproof were

crossed with a crown-and stem-rust resistant segregate from the cross Victoria×Richland at Aberdeen, Idaho, in 1934. In 1935, F_2 plants from these crosses were backcrossed with the Red Rustproof selection. F_1 plants were grown in the greenhouse at Arlington Farm in the winter of 1935–36, and data relating to the resistance of these F_1 plants to stem rust, crown rust, and smut have been reported (4). The F_2 generation was grown at Aberdeen in 1936, and the F_3 selections in the greenhouse at Arlington in 1936–37, where the plants were inoculated with stem and crown rusts and smut. The F_4 plants were grown in the Arlington greenhouse and subjected to crown and stem rusts and smut inoculations. In the autumn of 1938, seed of each of the rust- and smut-resistant plants of the F_4 generation was divided. Part of this material was sent to Tucson and the remainder was sown in the greenhouse at Arlington, where the plants were again tested for resistance to smuts and rusts in F_5. The F_5 plant rows at Tucson provided enough seed for nursery rows at Tucson, Denton, Stuttgart, Stoneville, Tifton, and Arlington in the fall of 1939. Pot cultures from smut-inoculated seed also were grown in the greenhouse at Arlington and inoculated with urediospores of crown and stem rusts. Other seed of the same 1938–39 crop was sown in the disease nursery at Ames in 1940, where additional information as to disease resistance was secured. From the various sowings mentioned, information was obtained on resistance to rusts and smuts and to cold, as well as on the probable yielding ability of the selections in various sections.

Beginning with the F_2 generation of the original cross, bulked seed and selections from the early and advanced generations, many of which had been tested for resistance to one or more of the diseases, were sent at various times to experiment stations throughout the winter oat belt for further selection and determination of winterhardiness and yield. Valuable observations for resistance to rusts and smuts also have been made at the cooperating stations.

As with the Nortex×Victoria and Fulghum×Victoria crosses, thousands of selections have been grown, many of which have been discarded because deficient in one or more of the characters for which the cross was made. It is pertinent to note that in a cross involving, as this one does, at least four distinct characters, in addition to those of usual agronomic significance, only a very small percentage of plants homozygous for all characters desired would be expected. These crosses are much less advanced than the Victoria×Nortex and Fulghum×Victoria crosses, and it is probable that additional desirable selections will be found. Pertinent data for the more promising selections for which winterhardiness and yield comparisons are available are given in Tables 2, 3, and 4. These selections resemble Red Rustproof in agronomic characteristics.

It will be noted (Table 2) that all of these selections are highly resistant to the most prevalent races of one or more of the three diseases here considered, and some of them appear to be resistant to all of them. The destructive effect of stem and crown rusts on susceptible Red Rustproof oat selections, as contrasted with high resistance of certain other selections, is illustrated in Fig. 1.

The resistance to both rusts of C. I. Nos. 3717, 3720, and 3725 should be noted. C. I. Nos. 3717 and 3720 are especially worthy because of their marked resistance to both rusts. Among other promising selections resulting from these crosses are C. I. Nos. 4061, 4062, 4063, and 4064. Data on their disease resistance are presented in Table 2. These selections were grown only in the west nursery at Arlington in 1940. Their survival percentages were estimated as being 85, 70, 70, and 85, and their average yields per rod row were recorded as 350, 365, 486, and 394 grams, respectively. From these

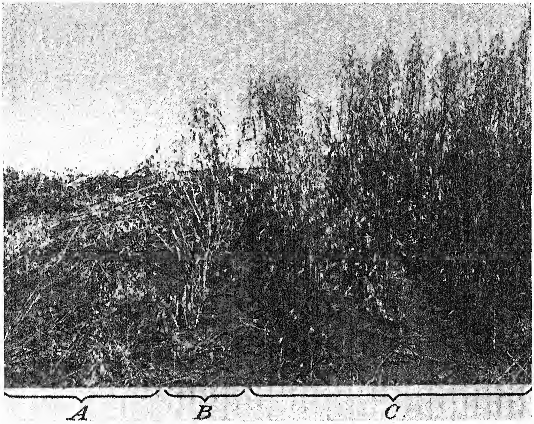

FIG. 1.—Segregates from Red Rustproof × (Victoria-Richland) hybrids, showing rust damage at Ames, Iowa, in 1940. A, susceptible to stem rust but resistant to crown rust; B, resistant to stem rust but moderately susceptible to crown rust; C, resistant to both stem and crown rusts.

crosses another promising selection is C. I. 3955, which equals or exceeds these four in all respects. C. I. 4096, a strain evolved from a cross between a Nortex-Victoria segregate and a Richland-Fulgham segregate, made in 1935, is resistant to both stem and crown rust and to smut. It gives promise also of hardiness, high yield, and early maturity.

It will be noted, also, that although some of these selections are not particularly winterhardy, one of them (C. I. 3712) is apparently equal to Appler and Nortex. Others, such as C. I. 3725, are almost as hardy. Since the data on winterhardiness are averages for five stations for one year only, their possible importance should not be over-emphasized.

TABLE 2.—*Reaction to crown rust, stem rust, and smut of promising Red Rustproof type selections from various oat crosses.*

C. I. No.	Type of rust infection at Arlington (greenhouse)*										% infection by smuts					
	1936		1937		1938		1939		1940		Arlington (greenhouse)					Ames (field) 1940
	Stem rust	Crown rust	Stem rust	Crown rust	Stem rust	Crown rust	Stem rust	Crown rust	Stem rust	Crown rust	1936	1937	1938	1939	1940	
					Red Rustproof (Tex. Selection 1415–8) × Victoria-Richland											
3707.....	4	0–2	1	2	2	2	2	2	0	2	0	33	0	0	0	0
3708.....	1–2	0–2	2	1–2	0	0	2	2	0	0	40	0	0	0	—‡	0
3710.....	0–2	2–3	2	3–4	—	—	—	—	0	0	33	0	—	0	0	0
3711 }.....	0–4	0–3	2	2–3	—	—	—	—	0	3	0	0	—	—	0	0
3712 }.....					—	—	—	—	2	0			—	—	0	0
4061.....	0–4	0–3	2	3–4	—	—	—	—	0	2	0	0	—	—	0	—
4062.....	0–2	2	2	2–3	2	0	1	2	0	0	0	0	0	0	0	—
					Victoria-Richland × Red Rustproof (Tex. Selection 1415–8)											
3702.....	0–3	2–3	2	2	2	0	3	0	0	2	0	0	0	0	0	0
3703.....	0–2	4	0	2–3	1	2	0	0	0	3	0	20	0	0	0	0
3704.....	0	3	0	1–2	1	2	0	2	0	0	0	33	0	0	0	0
3706.....	—	—	—	—	0	0–1	0	0	0	2	—	—	0	0	0	0
					Victoria-Richland × Red Rustproof[2] (Tex. Selection 1415–8)†											
3957 }....							0	0	0	1			0	0	0	—
3725 }....					0	1	0	0	0	1				25	0	0
3727 }....	0–2	3	0	2	0	0	0	2	0	1	0	50	0	0	0	0
3958 }....					0	0	0	0	0	0			0	0	0	—
4064 }....			0	2	0	0	0	0	0	1		0	0	0	0	—

Red Rustproof² (Tex. Selection 1415–8) × Victoria-Richland																
3716....			0–2	2–3	0	0	0	2	0	0		0	0	0	0	0
3717....							0	2	3	2			0	0	0	0
3720....	0	3	0	1–3	0	0	0	2	0	0	0	0	0	0	0	0
3722....			0	2–3	1	0	0	2	3	0		0	0	0	0	0
3724....			0	2–3	2	0	0	0	0	0		0	0	0	0	0
4063....			2–3	2–4	0	0	0	1–2	0	1		0	0	0	0	—
Nortex																
2382.....	3	3	0	2	3	3	–	—	4§	4§	‡	—	—	—	0	0
Victoria																
2401.....	—	0	4	2	4	0	0	0	4	2	—	—	25	0	0	—
Richland																
787.....	—	—	—	—	0	0	0	3	2	4	—	—	—	40	‡	—
Boone																
3305.....	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0

*The type of infection is the index frequently used by plant pathologists. By this, type 0 indicates no infection. Types 1 and 2 *indicate* the presence of rust pustules but of types termed resistant. Types 3 and 4 indicate the presence of rust pustules of the susceptible type. Type 4 indicates no resistance whatever is present.

†The exponent here indicates the number of backcrosses to the recurring parent.

‡Smut was present but percentage was not determined.

§Appler grown instead of Nortex in 1940.

TABLE 3.—*Estimated survival of Red Rustproof type oat selections grown at cooperating stations in 1940.*

C. I. No.	Arlington, Va.		Tifton, Ga., %	Stoneville, Miss., %	Stuttgart, Ark., %	Denton, Tex., %	Average	
	East, %	West, %					5 stations, %	In percentage of Appler
Red Rustproof (Tex. Selection 1415-8) × Victoria-Richland								
3707	10	10	100	10	6	6	8	10.7
3708	75	45	100	65	56	30	54	72.0
3710	20	30	100	65	76	60	50	66.7
3711	60	67	100	75	87	60	70	92.0
3712	80	55	100	82	83	75	75	100.0
Victoria-Richland × Red Rustproof (Tex. Selection 1415-8)								
3702	10	5	100	30	5	1	10	13.3
3703	82	65	100	75	74	45	68	90.7
3704	30	15	100	40	6	5	19	26.0
3706	20	30	100	23	1	0	15	20.5
Victoria-Richland × Red Rustproof^{2*} (Tex. Selection 1415-8)								
3725	85	65	100	75	79	50	71	97.3
3726	75	62	100	75	75	10	69	94.5
3727	80	50	100	75	83	20	62	84.9
Red Rustproof^2 (Tex. Selection 1415-8) × Victoria-Richland								
3716	45	30	100	82	83	50	58	79.5
3717	60	45	100	75	56	30	47	64.4
3720	60	50	100	88	78	30	61	84.9
3722	45	40	100	75	61	40	54	74.0
3724	65	60	100	55	53	40	55	75.3
Appler (Average of Checks)								
1815	35	65	100	95	94	80	74	100.0

*The exponent here indicates the number of backcrosses to the recurring parent.

As would be expected, the yield of strains that are not winterhardy is low at those stations (Stuttgart, Ark., and Denton, Tex.) where winter injury occurred. Generally, however, they gave a good account of themselves, and the non-winterhardy selections did well in those cases where winterkilling was not a limiting factor. Since there are certain areas in the South where winterkilling ordinarily is not severe, some of the strains somewhat lacking in winterhardiness may prove of value. Unfortunately, few of the selections grown in the test at Tifton were harvested for yield. Consequently, no yield data are presented in Table 4 for that station.

OTHER CROSSES OF RED OATS WITH VICTORIA-RICHLAND

Among the numerous crosses made at Aberdeen, Idaho, in 1934 and 1935 were many made to combine the disease resistance of segregates from the Victoria-Richland cross (11) with oats of other types. Red oats, such as Fulghum and Fulton (8) and other segregates from Fulghum×Markton crosses (4), were used extensively to produce

TABLE 4.—*Yield in grams per rod-row (15 feet) of Red Rustproof type oat selections grown at cooperating stations in 1940.*

C. I. No.	Arlington, Va. East, %	Arlington, Va. West, %	Stoneville, Miss., %	Stuttgart, Ark., %	Denton, Tex., %	Tucson, Ariz., %
Red Rustproof Tex. Selection 1415–8 × Victoria-Richland Selection 5542–1						
3707	151	36	99	0	93	615
3708	290	127	381	144	466	462
3710	132	120	325	205	351	339
3711	373	210	422	184	543	369
3712	307	164	419	282	574	523
Victoria-Richland Selection 5542–1 × Red Rustproof Tex. Selection 1415–8						
3702	270	155	415	239	47	297
3703	150	22	175	0	580	638
3704	221	145	259	84	184	492
3706	90	150	173	0	0	454
Victoria-Richland × Red Rustproof^{2}* (Tex. Selection 1415–8)						
3725	373	355	480	456	790	462
3726	280	312	318	153	546	626
3727	307	190	443	341	760	619
Red Rustproof^{2} (Tex. Selection 1415–8) × Victoria-Richland						
3716	320	257	444	313	563	370
3717	267	247	533	310	660	623
3720	299	251	450	320	810	552
3722	242	150	378	226	680	544
3724	300	423	441	250	680	477
Appler (Average of Checks)						
1815	315	346	526	384	775	620

*The exponent here indicates the number of backcrosses to the recurring parent.

disease-resistant red oats for spring sowing. Many red oat selections, highly resistant to all three diseases, have resulted; and, whereas these would not ordinarily have been expected to be very cold resistant, a few of them, notably C. I. 3991 from the cross Victoria-Richland×Fulton and C. I. Nos. 4000 and 4002, resulting from other Victoria-Richland×Fulghum-Markton crosses, have survived surprisingly well when fall sown at several stations and have produced yields comparing favorably with those from Red Rustproof-type strains in the same tests. Consequently, there is reason to expect some strains from this group of red oat crosses that will prove sufficiently hardy for sowing in the extreme southern portion of the fall-sown oat area.

SUMMARY

Extensive attempts to breed oats resistant to crown rust for fall seeding in the southern states met with little success until the discovery of unusual resistance in the Victoria and Bond varieties. Victoria also is resistant to the races of smut occurring in the winter-oat belt. When crown-rust resistant strains from crosses of Victoria with Nortex and Fulghum and other crown-rust resistant oats were

destroyed by stem rust, the hitherto unrecognized importance in the South of resistance to the latter disease also became evident. Stem- and crown-rust resistant strains from a Victoria-Richland hybrid were then crossed with varieties of winter oats.

The first crosses reported herein were Victoria×Nortex and Victoria×Fulghum. Thousands of selections from these crosses have been tested for winterhardiness, yield, and other agronomic characters and for resistance to crown rust and smut in the greenhouses at Arlington, Va., and Ames, Iowa, and in the field at cooperating stations throughout the southern United States. Some of these selections are extremely promising, and three of them, Ranger, Rustler, and Fultex, have been named and distributed to farmers. These are resistant to crown rust and smut but not to stem rust. Fultex appears especially winterhardy for a red oat.

In other crosses involving Richland, Victoria, and Red Rustproof, the stem rust resistance of Richland, the crown-rust and smut resistance of Victoria, and the winterhardiness and other desirable characteristics of Red Rustproof have been combined in several selections. Also, preliminary observations indicate that certain segregates of other crosses involving Victoria and Richland and either Fulton or other Fulghum×Markton selections may prove suitable for fall seeding in the deep South.

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PASTURE STUDIES OF BROME GRASS, *BROMUS INERMIS* LEYSS[1]

R. F. Fuelleman and W. L. Burlison[2]

TWENTY-FIVE years ago Mosher (1)[3] stated that "smooth brome grass makes a rank growth, and is gradually spreading over the whole United States. It was introduced as a forage grass, but lately has been considered of little value." Today agronomists are attempting to find the best methods of establishing and maintaining stands of smooth brome grass, *Bromus inermis* Leyss. It is the opinion of many investigators that brome grass ranks among the more important of the forage grasses in the midwestern states and will assume greater importance with increased knowledge of soil requirements, methods of seeding, and management.

In Illinois the acreage of brome grass seeded for pasture and hay is increasing; however, the total acreage is not large, presumably because of the slow establishment, difficulty of seeding, and attempts to grow the crop on soils of relatively low fertility. With an increased knowledge of the qualities of brome grass and a greater number of adapted strains of seed, the ultimate acreage can be expected to reach large proportions.

The Agronomy and Animal Husbandry Departments of the Illinois Agricultural Experiment Station are cooperating in a series of pasture investigations, including studies of smooth brome grass. This paper presents the results of experimental studies conducted during the years 1935 to 1940, inclusive.

TREATMENTS AND METHODS

The 5-acre field used in this investigation was previously used in a typical corn belt rotation of corn, corn, small grain, and sweet clover. It has a high level of productivity and has the added advantage of receiving some fertilizer elements through the medium of any excess surface water draining from experimental hog lots located at a slightly higher elevation. The slope of the field is gentle, approximating 2%, with a small ditch draining the field from north to southwest.

Following seedbed preparation, the field was seeded on April 20, 1933, with a mixture of Kentucky bluegrass 10 pounds, brome grass 15 pounds, redtop 7.5 pounds, and white clover 5 pounds per acre. Establishment of all species was good, but during the hot, dry summer of 1934 the white clover was destroyed and the grass species alone survived.

Forage yields and consumption by livestock were obtained during each grazing season, except 1934 when only yield data were obtained. The methods of sampling have been described in previous papers (2, 3). Yields and consumption data presented in this paper are the averages of the "A" or "difference" method and the

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[3]Figures in parenthesis refer to "Literature Cited", p. 892.

"B" method with the exception of the seasons of 1939 and 1940. During these latter years yields were obtained using the "difference" method only.

During each season except 1937 botanical analyses and density of stand counts were made, using a point quadrat, hand separations of forage, or analyses of small sod samples. No single method can be used, for the most accurate plan of analysis is dependent on the season and the discretion of the investigator.

Chemical analyses of forage samples for protein, calcium, and phosphorus were made and are presented for 1935 to 1938, inclusive (Table 7). Chemical analyses for 1939 and 1940 are not complete at this writing.

Numbers, management, and type of livestock pastured each season were determined by the animal husbandmen. Hereford steers and heifers were used in 1935, 1936, 1939, and 1940. During 1937 and 1938 sheep were pastured on the field.

RESULTS AND DISCUSSION

PERSISTENCE OF BROME GRASS

Although a seed mixture was used in establishing this pasture, analyses made in 1936 showed that the vegetational cover was approximately 90% brome grass (Table 1). As stated previously, the method of botanical analysis depended upon the time of the season and the system deemed best by the investigator. Obviously, brome grass during the early growing season of May and June will mask other vegetation, such as Kentucky bluegrass and redtop, and a point quadrat will not give a true picture of the percentage of the latter species on the sward. As the season advances, however, the efficiency of this instrument increases, as the upper story of the vegetation consisting of brome grass will have been grazed, exposing the smaller and apparently less palatable bluegrass and redtop. A more accurate analysis of the vegetational cover can be made by using a point quadrat during the months of September or early October, but again depending upon the season with respect to precipitation and temperature.

TABLE 1.—*Percentage composition of pasture seeded with a mixture containing brome grass.*

Sampling date	Brome grass, %	Method of analysis	Kentucky bluegrass, %	Redtop, %
July 8, 1936	89.8	Sod analyses	8.9	1.36
Apr. 19, 1938	60.2	Forage separation	38.5	1.00
May 19, 1939	65.3	Sod analyses	32.9	1.80
Aug. 21, 1939	57.1	Point quadrat	42.9	Trace
Oct., 1940	50.0	Point quadrat	49.0	Trace

Brome grass, according to some investigators, becomes "sod bound," unthrifty, and unproductive. In a short time many such pastures are said to be brome grass in name only. That this is true with respect to a decline in the amount of brome grass in the pasture described here is shown in Table 1. However, the decline is very slow. On this experimental pasture, during the forepart of the grazing season, the relative stand of brome grass in each succeeding year

appeared to equal that of any preceding year following establishment. Although one of the factors militating against the use of brome grass in a permanent pasture has been its lack of longevity, it is believed that this pasture demonstrates clearly that if after 7 years approximately 50% of the vegetation is brome grass, this grass can unequivocally be recommended as a grass suited for permanent pasture seedlings.

The relative palatability of a pasture plant is a concurrent determining factor in its longevity. It has often been observed that cattle and sheep have a distinct preference for brome grass over Kentucky bluegrass. From the standpoint of longevity, it is evident that this preference works to the disadvantage of brome grass, for both cattle and sheep graze it almost exclusively during the forepart of the season and continue to crop it during the hot, dry summer months when bluegrass is dormant. Following the decrease in available top growth of the brome grass, the livestock turn to bluegrass in the fall grazing period.

Brome grass grows very slowly during the fall months in the latitude of central Illinois, exhibiting some of the characteristics of winter crops in this respect. Slow recovery and growth in the fall grazing period are shown by the small residual yields obtained on the final sampling date during most seasons (Tables 3 and 4).

GRAZING MANAGEMENT

The number of animals pastured and the animal unit days of pasturing obtained are indications of management practices. This field was used in most seasons in a comparative test with Kentucky bluegrass, orchard grass, and reed canary grass. An attempt was made to stock each field according to its estimated seasonal carrying capacity. The number of animals placed on the field was sufficient only to graze it moderately, thus assuring sufficient vegetation to carry the livestock through the summer. Grazing periods were usually of 28 days' length but were changed as the amount of vegetation available necessitated. Animals were removed before serious overgrazing took place. The condition of the pasture and of the livestock rather than the calendar have been considered as the governing factors.

Table 2 shows that during the season of 1938 the grazing period was 182 days and the total animal unit days was 1,015.5. This season

TABLE 2.—*Animal unit days pasturage for seasons, 1935–40.*

Year	Total days on pasture	Animal unit days per acre	Total animal unit days for 5-acre field
1935	140	112	560
1936	112	112	560
1937	101	210	1,050
1938	182	203.1	1,015.5
1939	112	112 (cattle)	860
	50	60 (sheep)	
1940	188	146.1	730.5

was very favorable for pasture and the resulting number of animal unit days exceeded that of any season except 1937. Sheep were used during the 1938 season and seven sheep were calculated as the equivalent of one animal unit.

GRAZING DATA

On May 6, 1935, eight yearling steers were turned in on the north half of the field where they remained until September 23, a total of 140 days. The season was marked by moderate temperatures and an abundance of rainfall. Tables 3 and 4 present data for 1935 to 1940.

In 1936, 10 heifers were pastured on the 5-acre field from May 26 to September 15, a relatively short period made necessary by excessive heat and drouth. The field was closely grazed but removal on this early date, coupled with timely rains and moderate temperatures, resulted in rapid recovery. It should be noted that the cattle did not gain or lose weight during the period, July 21 to August 19, a period of excessively high temperatures. During this time the animals spent much of their time under a shelter. Acre gains in 1935 were 316.6 pounds, while in 1936 they were 268 pounds. The latter figure is an extremely large gain in weight when considered in the light of the shortness of the season and unfavorable weather conditions.

In both 1937 and 1938 sheep were used as grazing animals. The season in 1937 began on May 6 and forage was available to maintain the flock until July 29, a period of 84 days. Summer rainfall and temperatures were approximately average—using the previous 10-year weather records for comparison. The sheep were removed on July 29 and the pasture remained unoccupied until October 30 when a large group of Hereford calves was placed on the field for a period of 17 days. Yields during the period July 29 to October 30 were small (Table 3). Sheep are selective in their grazing habits and the pasture was eaten down to a point that showed evidence of overgrazing when they were removed. Obviously 39 ewes and 42 lambs were too large a number of animals for this 5-acre field. However, the fact remains that during this period of 84 days, acre gains totaled 217.4 pounds, an average daily gain of 2.56 pounds. The total gain for the flock was 1,087 pounds. Undoubtedly, by taking advantage of the early growth period of brome grass when it is high in protein and minerals, animals gain very nearly as much weight as during the entire season (Table 3). The Hereford calves used during the late fall period made large gains in weight, but evidently these gains were due only in part to pasturage, although no supplement was fed. These calves were removed from a stock train and placed on pasture immediately after weighing and thus regained certain shrinkage losses usually occurring in transit. The amount of pasturage available to this group of calves was sufficient, although the yield data for the final sampling period for 1937 were negative. Negative yields occur frequently as a mathematical result when the "difference" method of computation is used. Yield, consumption, and chemical analyses data have been published previously (2, 3).

Rainfall and temperatures during 1938 were comparable to those of 1935 (Table 5). The resulting rapid growth of brome grass gave

TABLE 3.—*Agronomic and aninal husbandry data from brome grass pasture for 1935 to 1937, inclusive.*

Periods	Average period yields, pounds per acre	Average period consumption, pounds per acre	Residual yields, pounds per acre	Number of livestock	Total days on pasture	Animal unit days per acre	Total animal gain, pounds	Gain per acre, pounds	Gain per acre per day, pounds
				1935					
May 6–24	4,290.0	985.0	3,304	8 steers	18	14.4	663	132.6	7.37
May 24–June 21	2,899.5	2,274.5	3,929	8 steers	28	22.4	560	112.0	4.00
June 21–July 19	1,584.5	1,665.5	3,848	8 steers	28	22.4	90	18.0	0.64
July 19–Aug. 30	1,327.5	2,788.5	2,387	8 steers	42	33.6	240	48.0	1.14
Aug. 30–Sept. 23	299.0	2,196.0	490	8 steers	24	19.2	30	6.0	0.25
Total	10,400.5	9,909.5	2,792 (av.)		140	112.0	1,583	316.6	2.26 (av.)
				1936					
May 26–June 23	3,876.5	301.5	3,575	10 heifers	28	28.0	860	172.0	6.14
June 23–July 21	−468.0	1,428.0	1,679	10 heifers	28	28.0	310	62.0	2.21
July 21–Aug. 19	844.5	1,433.5	1,090	10 heifers	29	29.0	0	0.0	0.00
Aug. 19–Sept. 15	457.0	1,233.0	314	10 heifers	27	27.0	170	34.0	1.26
Total	4,710.0	4,396.0	1,665 (av.)		112	112.0	1,340	268.0	2.39 (av.)
				1937					
May 6–June 8	4,312.0	1,976.0	2,335	39 ewes 42 lambs	34	68.0	—*	—	—
June 8–July 1	913.5	596.0	2,651	39 ewes 42 lambs	22	44.0	721.5	144.3	7.91
July 1–July 29	1,717.5	1,645.0	2,725	39 ewes 42 lambs	28	56.0	365.5	73.1	2.11
July 29–Aug. 16	184.0	0.0	2,499	0	0	—	—	—	—
Aug. 16–Oct. 30	133.0	0.0	2,007	0	0	—	—	—	—
Oct. 30–Nov. 17	−194.0	1,355	458	30 calves	17	42.0	2,530.0	506.0	36.14
Total	7,066	5,572	2,113 (av.)		101	210.0	3,617.0	723.4	15.39 (av.)

*Period gains not available.

TABLE 4.—*Agronomic and animal husbandry data from brome grass pasture for 1938 to 1940, inclusive.*

Periods	Average period yields, pounds per acre	Average period consumption, pounds per acre	Residual yields, pounds per acre	Number of livestock	Total days on pasture	Animal unit days per acre	Total animal gain, pounds	Gain per acre, pounds	Gain per acre per day, pounds
				1938					
Apr. 4–May 12	3,055.5	1,170.5	986	30 sheep	28	24.0	448	89.6	3.20
May 12–June 9	828.0	1,851.0	1,885	30 sheep	28	24.0	285	57.0	2.03
June 9–July 7	2,185.5	1,843.0	852	45 sheep	28	36.0	91	18.2	0.65
July 7–Aug. 4	2,143.0	1,614.5	1,194	45 sheep	28	36.0	195	39.0	1.39
Aug. 4–Sept. 1	425.0	1,222.0	2,649	45 sheep	28	36.0	30	6.0	0.21
Sept. 1–Sept. 13	—*	—	—	45 sheep	12	15.3	5	1.0	0.08
Sept. 13–Sept. 29	355.0	583.0	698	37 sheep	16	17.0	25	5.0	0.31
Sept. 29–Oct. 13	−49.5	390.5	258	37 sheep	14	14.8	28	5.6	0.40
Total	8,942.5	8,684.5	1,065 (av.)		182	203.1	1,117	221.4	1.03 (av.)
				1939					
May 1–May 26	1,955	461	1,494	5 steers	26	26.0	170.5	34.1	1.31
May 26–June 26	426	583	1,337	5 steers	30	30.0	196.5	39.3	1.31
June 26–July 24	526	149	1,714	5 steers	28	28.0	183.5	36.7	1.31
July 24–Aug. 21	139	543	1,310	5 steers†	28	28.0	169.5	33.9	1.21
Aug. 21–Oct. 2	1,249	1,577	982	42 sheep‡	31	37.2	—	—	—
Oct. 2–Oct. 21	501	−200	1,683	42 sheep	19	22.8	—	—	—
Total	4,796	3,113	1,420 (av.)		162	172.0	720.0	144.0	1.29 (av.)
				1940					
Apr. 24–May 20	1,612	842	770	6 steers	20	16.0	254.4	50.8	2.54
May 20–June 14	2,608	1,959	1,419	10 steers	28	37.2	730.8	146.2	5.74
June 14–July 12	−37	176	1,206	8 steers	28	29.8	109.7	21.9	0.78
July 12–July 26	202	373	75	6 steers	14	11.2	50.4	10.1	0.72
July 26–Aug. 23	405	748	190	4 steers	28	14.8	20.2	4.0	0.14
Aug. 23–Oct. 4	435	766	58	4 steers	42	22.4	379.7	75.9	1.81
Oct. 4–Nov. 1	−98	29	199	4 steers	28	14.8	−109.8	21.9	−0.78
Total	5,127	4,893	563 (av.)		188	146.2	1,435.4	287.0	1.57 (av.)

*Forage yields not obtained for this period.
†Received 3.1 pounds concentrate daily during this period.
‡Placed on pasture September 2 for balance of season. Weights of animals not obtained.

exceptionally large yields of dry matter during the spring and summer months (Table 4). Sheep were used as the grazing animals. Although the pasture season began on April 14 and ended on October 23, a period of 182 days, ample forage was available at all times. Referring again to Table 4, it will be noted that the period yields of dry matter were relatively small during the period August 4 to September 1 and a negative yield figure marked the final grazing period. Obviously, brome grass does not remain productive if allowed to mature seed. During the periods of rapid growth the sheep on the 5-acre field were unable to keep the pasture grazed closely enough to prevent it from maturing. From past observations it is evident that when brome grass has reached maturity its top growth is very slow. This is true under central Illinois conditions despite favorable temperatures and abundant rainfall.

TABLE 5.—*Precipitation in inches by weekly periods at Urbana, Illinois, for grazing seasons, 1935–40, inclusive.*

	1935	1936	1937	1938	1939	1940
Apr. 1–8	1.10	1.56	2.34	2.92	0.70	0.82
Apr. 9–15	0.80	0.06	0.61	—	2.90	1.04
Apr. 16–23	0.23	0.25	1.49	0.14	1.72	1.27
Apr. 24–30	0.74	2.30	0.96	0.36	0.07	0.83
May 1–8	3.60	1.42	1.36	0.40	0.26	1.50
May 9–15	1.58	0.46	0.01	0.64	0.06	0.55
May 16–23	1.01	1.00	1.22	3.08	0.56	1.31
May 24–31	0.74	1.06	—	0.85	0.31	1.17
June 1–8	0.31	0.26	3.13	0.64	0.47	1.43
June 9–15	0.13	0.09	0.82	1.60	3.61	1.40
June 16–23	2.39	0.01	0.60	—	1.19	0.63
June 24–30	0.81	0.11	0.88	3.43	0.90	1.58
July 1–8	1.72	—	0.10	1.36	0.99	—
July 9–15	0.84	0.43	1.59	0.10	—	0.80
July 16–23	0.64	0.10	—	2.46	0.74	0.02
July 24–31	0.92	0.82	0.74	2.53	—	0.13
Aug. 1–8	1.30	0.56	0.19	1.77	1.43	0.29
Aug. 9–15	0.80	1.58	0.44	0.11	1.06	0.33
Aug. 16–23	0.20	0.48	0.17	1.55	3.89	0.52
Aug. 24–31	0.06	0.92	—	0.85	—	1.66
Sept. 1–8	1.11	0.77	—	0.05	0.04	—
Sept. 9–15	1.11	1.38	3.12	0.24	—	0.48
Sept. 16–23	0.01	0.07	—	0.59	0.11	—
Sept. 24–30	1.71	3.61	2.22	—	0.17	—
Oct. 1–8	0.04	0.48	0.82	—	0.93	0.99
Oct. 9–15	0.44	0.86	0.33	0.71	1.16	0.42
Oct. 16–23	0.37	0.99	2.77	1.79	—	—
Oct. 24–31	0.80	1.16	—	—	0.45	0.52
Total	25.51	21.62	25.89	28.17	23.72	19.69

Thirty yearling sheep were placed on the brome grass pasture on April 14 and remained until June 9, 1938. On the latter date 15

TABLE 4.—*Agronomic and animal husbandry data from brome grass pasture for 1938 to 1940, inclusive.*

Periods	Average period yields, pounds per acre	Average period consumption, pounds per acre	Residual yields, pounds per acre	Number of livestock	Total days on pasture	Animal unit days per acre	Total animal gain, pounds	Gain per acre, pounds	Gain per acre per day, pounds
				1938					
Apr. 4–May 12	3,055.5	1,170.5	986	30 sheep	28	24.0	448	89.6	3.20
May 12–June 9	828.0	1,851.0	1,885	30 sheep	28	24.0	285	57.0	2.03
June 9–July 7	2,185.5	1,843.0	852	45 sheep	28	36.0	91	18.2	0.65
July 7–Aug. 4	2,143.0	1,614.5	1,194	45 sheep	28	36.0	195	39.0	1.39
Aug. 4–Sept. 1	425.0	1,222.0	2,649	45 sheep	28	36.0	30	6.0	0.21
Sept. 1–Sept. 13	—*	—	—	45 sheep	12	15.3	5	1.0	0.08
Sept. 13–Sept. 29	355.0	583.0	698	37 sheep	16	17.0	25	5.0	0.31
Sept. 29–Oct. 13	−49.5	390.5	258	37 sheep	14	14.8	28	5.6	0.40
Total	8,942.5	8,684.5	1,065 (av.)		182	203.1	1,117	221.4	1.03 (av.)
				1939					
May 1–May 26	1,955	461	1,494	5 steers	26	26.0	170.5	34.1	1.31
May 26–June 26	426	583	1,337	5 steers	30	30.0	196.5	39.3	1.31
June 26–July 24	526	149	1,714	5 steers	28	28.0	183.5	36.7	1.31
July 24–Aug. 21	139	543	1,310	5 steers†	28	28.0	169.5	33.9	1.21
Aug. 21–Oct. 2	1,249	1,577	982	42 sheep‡	31	37.2	—	—	—
Oct. 2–Oct. 21	501	−200	1,683	42 sheep	19	22.8	—	—	—
Total	4,796	3,113	1,420 (av.)		162	172.0	720.0	144.0	1.29 (av.)
				1940					
Apr. 24–May 20	1,612	842	770	6 steers	20	16.0	254.4	50.8	2.54
May 20–June 14	2,608	1,959	1,419	10 steers	28	37.2	730.8	146.2	5.74
June 14–July 12	−37	176	1,206	8 steers	28	29.8	109.7	21.9	0.78
July 12–July 26	202	373	75	6 steers	14	11.2	50.4	10.1	0.72
July 26–Aug. 23	405	748	190	4 steers	28	14.8	20.2	4.0	0.14
Aug. 23–Oct. 4	435	766	58	4 steers	42	22.4	379.7	75.9	1.81
Oct. 4–Nov. 1	−98	29	199	4 steers	28	14.8	−109.8	21.9	−0.78
Total	5,127	4,893	563 (av.)		188	146.2	1,435.4	287.0	1.57 (av.)

*Forage yields not obtained for this period.
†Received 3.1 pounds concentrate daily during this period.
‡Placed on pasture September 2 for balance of season. Weights of animals not obtained.

exceptionally large yields of dry matter during the spring and summer months (Table 4). Sheep were used as the grazing animals. Although the pasture season began on April 14 and ended on October 23, a period of 182 days, ample forage was available at all times. Referring again to Table 4, it will be noted that the period yields of dry matter were relatively small during the period August 4 to September 1 and a negative yield figure marked the final grazing period. Obviously, brome grass does not remain productive if allowed to mature seed. During the periods of rapid growth the sheep on the 5-acre field were unable to keep the pasture grazed closely enough to prevent it from maturing. From past observations it is evident that when brome grass has reached maturity its top growth is very slow. This is true under central Illinois conditions despite favorable temperatures and abundant rainfall.

TABLE 5.—*Precipitation in inches by weekly periods at Urbana, Illinois, for grazing seasons, 1935–40, inclusive.*

	1935	1936	1937	1938	1939	1940
Apr. 1–8	1.10	1.56	2.34	2.92	0.70	0.82
Apr. 9–15	0.80	0.06	0.61	—	2.90	1.04
Apr. 16–23	0.23	0.25	1.49	0.14	1.72	1.27
Apr. 24–30	0.74	2.30	0.96	0.36	0.07	0.83
May 1–8	3.60	1.42	1.36	0.40	0.26	1.50
May 9–15	1.58	0.46	0.01	0.64	0.06	0.55
May 16–23	1.01	1.00	1.22	3.08	0.56	1.31
May 24–31	0.74	1.06	—	0.85	0.31	1.17
June 1–8	0.31	0.26	3.13	0.64	0.47	1.43
June 9–15	0.13	0.09	0.82	1.60	3.61	1.40
June 16–23	2.39	0.01	0.60	—	1.19	0.63
June 24–30	0.81	0.11	0.88	3.43	0.90	1.58
July 1–8	1.72	—	0.10	1.36	0.99	—
July 9–15	0.84	0.43	1.59	0.10	—	0.80
July 16–23	0.64	0.10	—	2.46	0.74	0.02
July 24–31	0.92	0.82	0.74	2.53	—	0.13
Aug. 1–8	1.30	0.56	0.19	1.77	1.43	0.29
Aug. 9–15	0.80	1.58	0.44	0.11	1.06	0.33
Aug. 16–23	0.20	0.48	0.17	1.55	3.89	0.52
Aug. 24–31	0.06	0.92	—	0.85	—	1.66
Sept. 1–8	1.11	0.77	—	0.05	0.04	—
Sept. 9–15	1.11	1.38	3.12	0.24	—	0.48
Sept. 16–23	0.01	0.07	—	0.59	0.11	—
Sept. 24–30	1.71	3.61	2.22	—	0.17	—
Oct. 1–8	0.04	0.48	0.82	—	0.93	0.99
Oct. 9–15	0.44	0.86	0.33	0.71	1.16	0.42
Oct. 16–23	0.37	0.99	2.77	1.79	—	—
Oct. 24–31	0.80	1.16	—	—	0.45	0.52
Total	25.51	21.62	25.89	28.17	23.72	19.69

Thirty yearling sheep were placed on the brome grass pasture on April 14 and remained until June 9, 1938. On the latter date 15

animals were added to the above number. The original 30 sheep were unable to keep the grass grazed sufficiently close and a condition approximating undergrazing was evident. The additional animals, although unable to take advantage of all the pasturage available, aided materially in correcting the undergrazed condition.

Animal gains per acre for the season were 221.4 pounds (Table 4). It is of interest to note that 203.8 pounds of this gain were made during the period April 14 to August 4, indicating definitely that the greatest percentage of gain was made during the early part of the season when the forage was most nutritious.

Seasonal dry-matter yields were 8,942.5 pounds per acre, the highest yield since the season of 1935 (Table 4). This may be considered an indication of the longevity of brome grass, a basic factor in the potential increased use of this grass for pasture. The total consumption for the season was calculated as 8,685 pounds an acre. A comparison of yield and consumption figures shows that the ratio of consumption to yield was high and that the residual yield or forage remaining on the field was very small. This coincided with the actual condition of the pasture. The greater portion of growth, 90%, was made previous to August 4, and 75% of the total available forage was consumed by the same date. The relationship between animal gains, yield, and comsumption previous to August 4 is marked. A similar correlation is apparent during the latter part of the grazing season—animal gains, forage yields, and consumption per acre were equally small (Table 4).

Temperatures during the grazing season of 1939 were practically normal, but a deficiency of moisture occurred during the months of May, July, and September, extending into October. The immediate effect on seasonal yields was evident as shown by the comparatively low yield of dry matter. Total yield of dry matter was 4,796 pounds, approximately 60% of the 1938 yield. Consumption was calculated as 3,113 pounds (Table 6).

The north half of the field to which these data refer was used as pasture for five large steers beginning on May 1 and ending on August 21, a period of 112 days. The cattle were used in a comparative test with two similar groups of animals, one on brome grass, receiving supplementary feed, and the other in dry lot. On September 2, 42 sheep were placed on the brome grass pasture for a period of 50 days. These data are shown in Table 4.

Ninety per cent of the total yield of dry matter was produced previous to August 4, and, paralleling this, 75% of the total calculated consumption occurred before this date. From this it is evident that, although brome grass is considered drouth resistant, little growth occurs after August 1. Brome grass, characteristically, remains green and palatable during August and September in dry seasons while Kentucky bluegrass is dormant. This fact makes brome grass more acceptable to livestock and, if care in management is not exercised, the animals rapidly overgraze the field.

Gains by steers are shown in Table 4. Data on the sheep were not obtained because this flock was made up of miscellaneous small groups removed previously from the Agronomy experimental plots

TABLE 6.—*Calculated consumption of dry matter per pound of animal gain.*

Year	Total acre gain, lbs.	Consumption per acre, lbs.	Dry matter consumed per pound of gain, lbs.
1935	317.0	8,508	26.8
1936	268.0	4,395	16.4
1937*	217.0	4,217	19.4
1938	221.4	8,684	39.3
1939	144.0	3,113	21.6
1940	287.0	4,893	17.1

*Does not include figures for final seasonal grazing period.

RESULTS OF THE 1940 GRAZING SEASON

Agronomic and animal data for the 1940 grazing season are presented in Table 4. An abundance of forage was available as is indicated in the table. The total seasonal yield of dry matter was 5,092 pounds per acre. This was considered a relatively small yield, but moisture conditions were unfavorable during July and August, depressing growth and calculated consumption. As stated previously, the botanical composition, as determined by point quadrat studies, shows that approximately 50% of the vegetation was brome grass and 49% Kentucky bluegrass. Density of cover was 93%. These figures are convincing evidence of the persistence of brome grass in a permanent pasture.

The field was used as pasture for Texas steers from April 27 to November 1, a grazing season of 188 days. Animal gains per acre were 287 pounds. This was the largest acre gain registered for any of a series of pastures used in a comparative test which included Kentucky bluegrass, orchard grass, and reed canary grass. Average daily animal gains in conjunction with consumption and yields illustrate the close relationship existing between these three factors.

Calculated consumption data of forage per pound of animal gain for each season are shown in Table 6. The figures seem to indicate a relationship between consumption and the quantity of forage available. (Tables 3 and 4). High consumption figures are shown for the seasons 1935 and 1938, both better than average seasons for pasture productivity and animal gains. Sheep, particularly ewes, are not the best type of animal to use for comparisons of forage efficiency. Environmental factors are most important with respect to consumption and gains by livestock.

CONCLUSIONS

Smooth brome grass, *Bromus inermis*, Leyss, can be used as the principal species for seeding pastures desired for a period of 5 to 10 years' duration with the expectation that, with proper management, it will show a remarkable degree of persistency.

Chemical analyses (Table 7) made over a period of 4 years show a high protein and mineral content and are apparently related to good animal acre gains. The relationship needs more clarification in this respect.

In addition to such resistance to heat and to moisture deficiencies

TABLE 7.—*Chemical composition of forage samples from brome grass pasture for grazing seasons, 1935–38, inclusive.**

Sampling dates, 1935	Protein %	Ca %	P %	Sampling dates, 1936	Protein %	Ca %	P %
May 24	13.58	0.392	0.272	June 26	8.95	0.357	0.158
June 21	10.28	0.399	0.212	July 21	7.16	0.396	0.122
July 19	12.31	0.370	0.227	Aug. 24	10.12	0.375	0.178
Aug. 30	13.07	0.476	0.241	Sept. 15	19.26	0.463	0.269
Sept. 23	15.59	0.553	0.202				
Sampling dates, 1937	**Protein %**	**Ca %**	**P %**	**Sampling dates, 1938**	**Protein %**	**Ca %**	**P %**
June 8	11.19	0.288	0.265	May 13	16.57	0.386	0.288
July 1	7.76	0.236	0.268	June 10	12.47	0.264	0.216
July 29	11.69	0.351	0.193	July 8	15.74	0.391	0.295
Aug. 16	14.19	0.326	0.211	Aug. 5	18.19	0.385	0.274
Oct. 30	15.06	0.439	0.200	Sept. 1	14.72	0.403	0.323
Nov. 17	11.48	0.466	0.170	Sept. 29	20.89	0.444	0.236
				Oct. 14	15.03	0.454	0.355

*For "A" samples.

as brome grass may possess, it is also drouth escaping. Rapid spring growth and high early seasonal yields tend to prolong grazing through midsummer dry periods until the time when temperatures and precipitation are more favorable for fall growth recovery. If high temperatures continue through the early fall, little recovery takes place and the carrying capacity is limited. This conclusion can be attested by relating temperatures, precipitation, and animal gains with forage yields.

SUMMARY

Smooth brome grass seeded as approximately 40% of the pasture mixture in 1933 has persisted to a marked degree up to the present time (1940) and shows every indication of continuing as a dominant species in the sward. Late fall botanical analyses in 1940 showed that brome grass constituted 50% of the vegetation.

Yields and consumption have fluctuated with seasonal conditions but have been uniformly high when compared with other species of grasses (2). Pasture days and animal gains have been uniformly high in all seasons.

Small residual yields on final seasonal sampling dates indicate the slow recovery of brome grass following seasonal grazing.

Observations and data show that approximately 90% of the total growth occurs before August 1, and indicate that brome grass is not only drouth resistant but is also drouth escaping.

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GENETICAL CONSEQUENCES OF THE CHROMOSOMAL BEHAVIOR IN ORCHARD GRASS, *DACTYLIS GLOMERATA* L.[1]

W. M. Myers[2]

RECENTLY several perennial grass species have been found to behave cytologically as autopolyploids. Among these are *Dactylis glomerata* L. according to Müntzing (14, 15),[3] and Myers and Hill (19, 20, 21); the tetraploid race of *Agropyron cristatum* (L.) Beauv., according to Myers and Hill (19, 20); *Arrhenatherum elatius* (L.) Mert. & Koch., according to Kattermann (7), and Myers and Hill (19, 20); *Anthoxanthum odoratum* L., according to Kattermann (7), and *Hordeum bulbosum* L., according to von Berg (2). It is possible that critical cytological studies of more perennial grass species may reveal additional cases of autopolyploidy, or at least cases in which the chromosomal behavior indicates a constitution intermediate between auto- and allopolyploidy. Hexaploid *Phleum pratense* L. already has been placed in this latter category by the work of Nordenskiöld (22), Müntzing and Prakken (16), and Myers (18).

Theoretically, these autopolyploid species will show a polysomic type of inheritance. Few genetical data are available as yet for any of these grass species. In studies of the first inbred generation of plants of orchard grass from open-pollinated populations, Stapledon (25) found a striking deficiency in the recessive class in lines segregating for characters which he supposed were conditioned by a single factor pair. Using similar material of orchard grass, the writer found a few progenies showing ratios approaching 3:1 and also other progenies in which the deficiency in the recessive class was too great to be attributed to random sampling. Such deviations from the theoretical 3:1 ratio might have been due to inviability of the recessive types, to duplicate or triplicate factors conditioning the character, or to tetrasomic inheritance. The latter conclusion is fully in accord with the known meiotic behavior of orchard grass. Studies of segregation in the second inbred generation (I_2) from which the genotypes of the plants of the first inbred generation (I_1) can be determined should bring critical evidence to bear upon which hypothesis is correct.

Myers (17) has published the results of preliminary studies of I_2 progenies, which supported the hypothesis of tetrasomic inheritance. To obtain more extensive data on this question, plants of orchard grass were selected which were known from preliminary I_1 and I_2 tests to be heterozygous for factors conditioning albino seedlings, yellow seedlings, or both. Additional I_1 and I_2 progenies from each plant were grown and classified.

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[2]Geneticist.

[3]Figures in parenthesis refer to "Literature Cited", p. 900.

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

The genetics of autopolyploids has been studied by Muller (13), Blakeslee, Belling, and Farnham (3), Haldane (6), deWinton and Haldane (26), Lawrence (8, 9), Sömme (24), Sansome and Philp (23), Lindstrom (10), Mather (11, 12), and others. Since orchard grass is an autotetraploid, only the theoretical ratios expected from autotetraploids will be considered in this paper. Fundamentally, autotetraploids differ in meiotic and genetical behavior from diploids or allotetraploids in that four instead of two homologues of each chromosome are present. During prophase of meiosis, each set of four associates as a quadrivalent or at random as two bivalents and, at anaphase I, the four disjoin with two chromosomes moving to each pole at random. As a consequence, each spore receives two chromosomes of each kind, i. e., two of the eight chromatids of the four synapsing chromosomes. Thus, for any factor, Aa for example, three types of gametes, AA, Aa, and aa, and five types of zygotes, AAAA, AAAa, AAaa, Aaaa, and aaaa, are possible. These zygotic types have been called quadruplex, triplex, duplex, simplex, and nulliplex by Blakeslee, Belling, and Farnham (3), and this terminology will be followed in this paper.

The gametic output, and consequently the genotypic ratios among the progenies, will differ for these three heterozygous types. A further cause of variation in the expected gametic ratios is the locus of the particular gene with reference to the centromere. This is illustrated in Fig. 1. A plant is assumed to be triplex for two factors, A and B, where A is proximal and B distal in relation to the centromere. If crossing-over does not occur between A and the centromere, the first division will always be reductional for A, i. e., sister chromatids at this locus will always pass to the poles attached to the same centromere. In the second division, sister chromatids will be separated and sister alleles must always be included in different spores. As a result, the gametes AA and Aa will be produced in equal numbers and aa gametes will not be obtained. The behavior of gene B will be different in sporocytes in which a crossover has occurred, as shown in Fig. 1. As a result of the crossover between chromatids of the B and b chromosomes, the first division will be equational for the chromatids at the locus of B, i. e., sister chromatids at this locus are now attached to different centromeres. Consequently, sister alleles may be included in the same or in different spores, depending upon the distribution of the chromosomes at the two divisions.

The gametic and genotypic ratios expected from autotetraploids on the basis of the former behavior, i. e., chromosomal assortment, were first calculated by Muller (13) and Lawrence (8). Later, Haldane (6) gave a general formula for calculating these ratios for any autopolyploid. The consequences of crossing-over between the locus of the gene and the centromere (gene B in Fig. 1) were not recognized until after the demonstration of double strand crossing-over in *Drosophila* by Bridges and Anderson (4) and Anderson (1). Haldane (6) assumed that this type of behavior would result in purely random chromatid assortment for genes sufficiently distant from the centromere and presented a formula for calculating theoretical ratios on this assumption.

Sansome and Philp (23) stated that the distance from the centromere must be at least 50 genetic units to permit random chromatid assortment. Mather (11), however, showed that random chromatid assortment occurred only as a result of chance combination of the products of reductional and equational first divisions. In the theoretical case in which every first division is equational for the gene locus, he found that the expected proportion of homozygous types was higher and of heterozygous types lower than that expected from chromatid segregation.

For genes sufficiently removed from the centromere to permit double exchanges in every sporocyte, the expected ratios approach closely to those expected from random chromatid assortment, but the latter is not obtained even with larger numbers of exchanges. Since the regular occurrence of a single cross-over is improbable and since greater numbers of cross-overs result in ratios closely approaching random chromatid assortment, there seems to be a greater likelihood of obtaining ratios approximating those expected on the hypothesis of random chromatid assortment than those expected from completely equational first divisions. Therefore, ratios for this paper were calculated on the former basis.

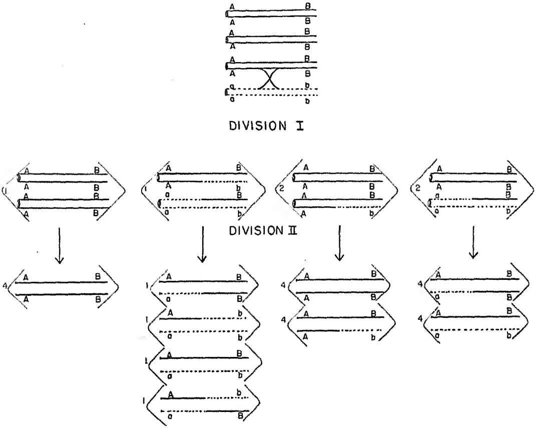

FIG. 1.—Gametic types expected from a triplex parent, with and without crossing-over between the gene and the centromere. The ratio shown for gene B will be obtained only if quadrivalents are regularly formed, and if disjunction from the quadrivalent is at random.

The expected gametic and zygotic ratios for each heterozygous type are given in Table 1. The breeding behavior in I_2 of the different I_1 genotypes is also given in this table.

EXPERIMENTAL RESULTS

Results in the I_1 and I_2 generations from two plants were consistent with the hypothesis of tetrasomic inheritance, assuming that the parents were duplex (AAaa). (See Table 2.) In the I_1 generation of plant No. 6 (13), a ratio of 202 normal:9 albino seedlings was obtained. Using X^2 for goodness of fit of observed to calculated, P lies between .10 and .20, according to Fisher (5), when the theoretical is calculated on the basis of no crossing-over between the centromere and the gene (calculated -A) and between .80 and .90, when the

theoretical is calculated on the basis of random chromatid assortment (calculated -B).[4] In the I_2 generation, 30 lines averaging 81.5 seedlings per line were classified. X^2 for fit to calculated -A gave P between .05 and .10, and when X^2 was calculated for each segregating line and total X^2 obtained, P was between .30 and .50. Using the theoretical from calculated -B, P lies between .20 and .30 for the I_2 lines and P for total X^2 of the segregating lines was between .05 and .10.

TABLE 1.—*Expected gametic products and breeding behavior from different types of heterozygotes.*

Genotype of parent	Gametes of parent	I_1 progeny		Breeding behavior in I_2
		Frequency	Genotype	
No Crossing-over Between Gene and Centromere				
AAAa	1AA	1	AAAA	Not segregating
	1Aa	2	AAAa	Not segregating
		1	AAaa	Seg. 35:1
Random Chromatid Assortment				
AAAa	15AA	225	AAAA	Not segregating
	12Aa	360	AAAa	Seg. 783:1
	1aa	174	AAaa	Seg. 20.78:1
		24	Aaaa	Seg. 2.48:1
		1	aaaa	Not segregating
No Crossing-over Between Gene and Centromere				
AAaa	1AA	1	AAAA	Not segregating
	4Aa	8	AAAa	Not segregating
	1aa	18	AAaa	Seg. 35:1
		8	Aaaa	Seg. 3:1
		1	aaaa	Not segregating
Random Chromatid Assortment				
AAaa	6AA	1.00	AAAA	Not segregating
	16Aa	5.33	AAAa	Seg. 783:1
	6aa	9.11	AAaa	Seg. 20.78:1
		5.33	Aaaa	Seg. 2.48:1
		1.00	aaaa	Not segregating
No Crossing-over Between Gene and Centromere				
Aaaa	1Aa	1	AAaa	Seg. 35:1
	1aa	2	Aaaa	Seg. 3:1
		1	aaaa	Not segregating
Random Chromatid Assortment				
Aaaa	1AA	1	AAAA	Not segregating
	12Aa	24	AAAa	Seg. 783:1
	15aa	174	AAaa	Seg. 20.78:1
		360	Aaaa	Seg. 2.48:1
		225	aaaa	Not segregating

In this and later cases in which the obtained ratio has been compared with calculated -B, it has been assumed that the I_2 progenies of triplex I_1 plants would not segregate. This assumption is not

[4]A and B are used in the following pages to indicate these two conditions.

strictly correct. Triplex plants are expected to segregate in a ratio of 783:1 and occasional segregating progenies would be expected even when the numbers of plants per progeny are about 100 as in these cases. When such segregates are obtained, the parent plant is then incorrectly classified as duplex, i.e., it is assumed that the progeny is segregating in a ratio approximately 20.78:1. Therefore, it might be expected in general that the obtained values for "not segregating" lines would be too low and for lines segregating 20.78:1 too high. An approximate correction can be made for this error by calculating the number of triplex plants in each family which would be expected to show recessive segregates and, in the calculated ratio, shifting this number of families from the "not segregating" to the "segregating 20.78:1" class. By correction in this manner, the fit of observed to calculated would tend to be improved in the families reported in this paper.

TABLE 2.—*Observed and calculated ratios in I_1 and I_2 of duplex plants.*

	Normal	Segregating		Albino	Value of P	Value of P for total X^2
		35:1 or 20.78:1	3:1 or 2:48:1			
		6 (13) I_1 Generation				
Observed.....	202.00	—	—	9.00	—	—
Calculated A*	205.14	—	—	5.86	0.10 to 0.20	—
Calculated B..	201.31	—	—	9.69	0.80 to 0.90	—
		6 (13) I_2 Generation				
Observed.....	12.00	9.00	9.00	—	—	—
Calculated A..	7.71	15.43	6.86	—	0.05 to 0.10	0.30 to 0.50
Calculated B..	9.14	13.16	7.70	—	0.20 to 0.30	0.05 to 0.10
		42 (23) I_1 Generation				
Observed.....	231.00	—	—	14.00	—	—
Calculated A..	238.20	—	—	6.80	less than 0.01	—
Calculated B..	233.75	—	—	11.25	0.30 to 0.50	—
		42 (23) I_2 Generation				
Observed A...	14.00	24.00	11.00	—	—	—
Calculated A..	12.6	25.2	11.2	—	0.90	0.40 to 0.50
Observed B...	14.00	25.00	10.00	—	—	—
Calculated B..	14.94	21.49	12.58	—	0.50 to 0.70	less than 0.01

*A = No crossing-over between the gene and centromere; B = Random chromatid assortment.

The inclusion of families segregating 783:1 with those segregating 20.78:1 likewise introduces an error in the calculation of total X^2. Here again, an approximate correction could be made and this correction would tend to increase the value of P for total X^2 in most of the families.

Use of these corrections, however, would not alter in any way the conclusions drawn regarding the type of inheritance in *Dactylis glomerata*. Furthermore, it is the opinion of the author that the accuracy of such corrections would be seriously limited by the small

number of I_2 lines grown in each family. Therefore, no corrections have been made in this paper.

The behavior with plant No. 42 (23) was similar to that found with plant No. 6 (13). In the I_1 generation, P was less than .01 for calculated -A and between .30 and .50 for calculated -B. From these results it might have been concluded that the gene was sufficiently removed from the centromere to give random chromatid assortment. This conclusion was not supported, however, by the behavior in I_2. In I_2, 49 lines averaging 115.7 seedlings per line were classified. Of these, 14 lines were not segregating and 35 were segregating. Of the segregating lines, 24 fitted closely to the 35:1 or 20.78:1 ratio and 10 fitted the 3:1 or 2.48:1 ratio. One line was intermediate. Using calculated -A, this line approached more closely to 3:1, while using calculated -B, it approached more closely to 20.78:1. For fit of the I_2 lines to calculated -A, P is .90, while for fit to calculated -B, P lies between .50 and .70. Total X^2 for fit of segregating lines to calculated -A gave P between .40 and .50, while total X^2 for fit of the segregating lines to calculated -B gave P of less than .01. The high X^2 in the latter case was caused primarily by the one line in which the ratio was intermediate.

The I_1 and I_2 behavior of three parent plants indicated that these plants were triplex (Table 3). In the case of plant No. 2 (21), 323 I_1 seedlings were classified and all were normal. Among the 43 I_2 lines,

TABLE 3.—*Observed and expected ratios in I_1 and I_2 of triplex plants.*

	Normal	Segregating		Albino or yellow	Value of P	Value of P for total X^2
		35.1 or 20.78:1	2.48:1			
		2 (21) I_1 Generation				
Observed.....	323.00	—	—	0	—	—
		2 (21) I_2 Generation				
Observed.....	33.00	9.00	1.00	—	—	—
Calculated A*	32.25	10.75	0.00	—	—	—
Calculated B..	32.13	9.56	1.32	—	0.90 to 0.95	Less than 0.01
		6 (13) I_1 Generation				
Observed.....	202.00	—	—	0	—	—
		6 (13) I_2 Generation				
Observed.....	17.00	12.00	1.00	—	—	—
Calculated A..	22.5	7.5	0.00	—	—	—
Calculated B..	22.41	6.67	0.91	—	0.05 to 0.10	0.05 to 0.10
		42 (23) I_1 Generation				
Observed.....	231.00	—	—	0	—	—
		42 (23) I_2 Generation				
Observed.....	35.00	14.00	0.00	—	—	—
Calculated A..	36.75	12.25	0.00	—	0.90 to 0.95	0.01 to 0.02
Calculated B..	36.61	10.89	1.50	—	0.10 to 0.20	0.02 to 0.05

*A = No crossing-over between the gene and centromere; B = Random chromatid assortment.

33 were not segregating, 9 were segregating 20.78:1, and 1 was segregating 2.48:1 for albino seedlings. The presence of the line segregating 2.48:1 indicates that crossing-over must have occurred between the gene and the centromere and that the expected should more closely approximate calculated -B. A value of P of .90 to .95 indicates a good fit of observed to calculated. Total X^2 for the segregating lines gave P of less than .01. In this case, X^2 for 9 of the 10 segregating lines was less than X^2 for P of .05.

The behavior in I_1 and I_2 of plant No. 6 (13) is similar to that in plant No. 2 (21) except that yellow instead of albino seedlings were involved. The results are consistent with the hypothesis of random chromatid assortment. With plant No. 42 (23), no yellow seedlings were obtained in 231 I_1 plants but 14 of the 49 lines showed ratios of green vs. yellow approximating 35:1 or 20.78:1. The fits of observed to calculated -A and to calculated -B were both satisfactory.

DISCUSSION

It is apparent from the data presented in Table 2 that by use of progenies of a duplex plant, it is not possible, at least with the numbers used in these experiments, to determine whether the gene is distal or proximal with reference to the centromere. The occurrence of crossing-over between the gene and the centromere can be detected more readily among the progenies of triplex or simplex plants. In the I_1 generation of a triplex plant, recessive plants will occur only as a result of crossing-over. However, even on the assumption of random chromatid assortment only 1 out of 784 is expected. In the I_2 generation, progenies segregating 2.48:1 can be obtained normally only as a result of crossing-over between the gene and the centromere. Furthermore, on the basis of random chromatid assortment, an average of 1 out of 32.6 plants of the dominant I_1 phenotype will be expected to segregate in this manner. In the I_1 generation of a simplex plant, no triplex or quadruplex plants are expected in the absence of crossing-over between the gene and the centromere. Therefore, the occurrence of plants of either type, as revealed by the I_2 or other tests, is evidence of crossing-over. In the hypothesis of random chromatid assortment, 1 out of 22.4 of the dominant phenotype is expected to be triplex or quadruplex.

Plant genetical research has been concerned primarily with diploid or more rarely with allopolyploid species. Likewise, the plant breeder has had to deal almost exclusively with diploids and allopolyploids. The genetical results which have been reported for autopolyploid species are in agreement with those expected on the basis of their meiotic behavior and indicate that the geneticist and plant breeder will be faced with different and, in many ways, more complex problems in this sort of species.

SUMMARY

The results presented in this paper are in agreement with the hypothesis of tetrasomic inheritance in *Dactylis glomerata*. This type of inheritance is expected from the meiotic behavior in this species.

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SUCROSE LOSS AND CHANGES OF NITROGEN CONSTITUENTS IN SUGAR BEETS UNDER CONDITIONS OF DELAYED TOPPING[1]

Charles Price, James M. Fife, Glenn E. Gillespie, and William C. Ferguson[2]

SOME sugar beet growers in certain parts of California have followed the practice of severing the beet roots from the soil several days in advance of topping and hauling them to the factory for processing. It has been assumed that if the leaves are left attached the sucrose in them will move down into the roots and increase the amount of available sugar for extraction. The practice has been further defended on the assumption that loss in weight by drying is compensated by an increase in sucrose percentage and that savings may be effected by the reduction in costs of hauling.

Larmer (3)[3] conducted field tests with delayed topping at Davis, California, in 1933 and 1934 in which he compared the results obtained from sugar beets grown in replicated plots which were harvested immediately after lifting with those obtained from plots in which the roots were harvested later; topping being delayed 1, 2, and 3 days in the 1933 experiment and approximately 1, 2, 3, and 4 days in the 1934 trials. He concluded that the increase in sucrose percentage shown when harvest was delayed was assignable to desiccation of the root tissues. He found rather consistently lower total sugar yields associated with delayed harvesting, and concluded that the postulated translocation of sugars from foliage to the root had been over emphasized. Under the conditions of his experiments, however, the sugar losses found did not reach significance. In the absence of evidence of gain in sugar yields, he pointed out that advantages from delayed harvesting would need to be based on economies in handling the crop for delivery, at the same time calling attention to the undesirability of flaccid beets for processing.

Considerable European literature having more or less bearing on the general subject of changes taking place in sugar beet roots under drying conditions has accumulated. All reports agree that respiration and metabolic processes continue after the root connections with the soil are broken. Massa (4) has shown that freshly dried and topped beets lose sugar by respiration rapidly for 6 or 8 days after which the rate of loss slackens. Oparin, et al. (6) reported that the gradual wilting of the beet root had no marked influence on respiration. As to translocation, various claims of gains in sucrose with delayed topping have been made in certain popular articles. Novak (5), on the other hand, in a thorough study of movement of sugar from sugar beet leaves to roots under conditions of drying, found that in none of his experiments could such movement be shown. In his review of the work of other investigations, he stated that error was made by not taking

[1]Contribution from the Division of Sugar Plant Investigations, U. S. Dept. of Agriculture. Received for publication June 3, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 907.

into account tests under identical conditions since more rapid drying occurs in beets with tops intact than in roots with tops detached.

Apparently, detailed studies on the effect of severe drying on the nitrogen constituents of the roots with tops intact or under field conditions of delayed topping have not been made. Braun (2), in tests on predigging in Silesia, found in the case of mature beets that, "the sucrose content of the root relatively speaking increased more than the water content decreased; there was, therefore, an actual increase of sugar production per surface unit. The content of crude protein also increased, the purity of the juice increased, but simultaneously also the harmful nitrogen increased." He also states that, generally speaking, immature beets gave results that were contrary to those obtained with mature beets; i. e., there was a return movement from the root to the leaf. These beets therefore lost in value.

The experiments here reported re-examine the effect of delayed topping on sucrose percentage and the apparent purity coefficient. In addition, the possibility has been considered that under conditions of delayed topping in California changes in nitrogen constituents may take place leading to an increase of that nitrogen fraction which is designated by sugar chemists as "harmful" nitrogen (7), because of its interference with recovery of sugar in processing.[4]

MATERIALS AND METHODS

In 1936, 1937, and 1938, sugar beets growing under normal field conditions were used for the study of the effects of delayed topping. The 1936 tests at Chino, California, although of the same general type as those at King City in 1937 and 1938, afforded only limited amount of data because of variability of the field in soil type. The King City tests afforded reliable samples throughout the entire experimental area from which to determine the usual agronomic and chemical attributes as well as the samples for analysis of nitrogen constituents.

The plan of experimentation followed at King City in 1937 was to select 20 rows approximately 500 feet long in a field of the curly top resistant variety U. S. 33. The beets were grown in beds according to the common California practice. The field chosen had an exceptionally good stand of beets spaced with a high degree of uniformity in the rows. On a date which corresponded closely with that used for the rest of the field, all the sugar beets in the experimental area were lifted with a beet lifter. This operation severed the roots from the soil and raised the crowns slightly above their growing position. Immediately after lifting, the sugar beets were picked up at random, the entire experimental area being traversed in sampling. Only normal, competitive beets were chosen, that is plants which had other healthy beets standing opposite in the row on either side.

The 400 sugar beets taken as a sample from the entire plot were divided at random into the major groups. Each major group was then subdivided into ten 20-beet samples. Weight of sucrose and apparent purity coefficient determinations were made on each of the 20-beet samples. Statistical comparisons of the data obtained showed that differences between the two major groups did not vary significantly in the attributes measured. It was concluded, therefore, that 200 plants constituted an adequate sample. The concordance among the 20-beet

[4]Roemer defines harmful nitrogen (page 84) as, "those nitrogen constituents which go over in the diffusion juice and increase processing difficulties, since they are not sufficiently recovered through the customary purification methods. One obtains these nitrogenous constituents by subtracting the content in protein ammonia and amid-nitrogen from the total nitrogen."

samples further indicated that the sugar beets in the entire plot were suitable for a test of this kind since no widely variant values were obtained.

As mentioned, the sampling at Chino in 1936, in an experiment conducted along the same line, did not meet these criteria, hence observations were limited to a small sampling in a uniform area for nitrogen determinations only.

The other samplings at King City in 1937 made at 24-hour intervals from the experimental area followed the same procedure, except that 200 beets divided up into ten 20-beet samples were used. Samples were taken immediately and 1, 2, 3, 4, 5, 6, and 7 days after lifting.

The 1938 tests at King City essentially repeated the 1937 tests, the sampling in all cases consisting of 200 beets as 20-beet samples.

Root yield has been calculated to acre basis for 100% stand for the average weight of roots determined from the sample. The acre yield of indicated available sugar has been calculated by multiplying the acre yield of roots in pounds by the sucrose percentage and then multiplying this product by the apparent purity coefficient as a percentage factor.

CHEMICAL ANALYSES

Determinations of sucrose percentages and apparent purity coefficient have followed the procedure used by the Division of Sugar Plant Investigations, U. S. Dept. of Agriculture. The 20-beet sample was washed, drained, and then weighed. Each root of the sample was split longitudinally and the half-root pieces were then passed under a circular rasp which ground a fine pulp from a section. The construction of the rasping apparatus is such that the pulp from each succeeding half root is thrown from the circular rasp onto a metal band, so that the entire mass of pulp from the 20 beets is spread on the band as a series of layers. The pulp is then taken from the band and thoroughly mixed by an electrically operated mixer. Two hundred grams of each composite sample of pulp were placed in a freezing chamber in which it was kept, in frozen condition, until analyzed for nitrogen constituents.

Twenty-six grams were taken for determination of sucrose percentage and of total solids by refraction, the one-solution method as devised by Bachler (1) being used. Extraction of sucrose was by the cold water digestion method of Krueger as modified by Sachs-Le Docte. As a check on reliability of the cold water extraction of sucrose, considering the relatively coarse pulp from flaccid beets in the samples obtained after 1 to 7 days delay in topping, comparative tests were run with the hot-water digestion method using pulp from both fresh and flaccid beets. There was no significant difference in sucrose percentage or coefficient of apparent purity between the two methods.

The methods used for determining harmful nitrogen were essentially those developed by European investigators. These are outlined below. All samples were treated in the same manner, consequently, all errors were eliminated by mutual cancellation.

To determine the harmful, soluble, ammonia plus amid and the nitrogen not precipitated by copper hydroxide, 100 grams of beet pulp were extracted with 450 cc of warm water. The extract was filtered and made up to a volume of 500 cc. Two 50-cc aliquots were brought to boiling and sufficient acetic acid added to precipitate the proteins. Soluble nitrogen was determined on the filtrates by a standard method (nitrates were not included). The remaining 400 cc were heated to a temperature of 85° C and 50 cc of a copper sulfate solution (60 grams of copper sulfate to 1,000 cc of water) and 50 cc of a sodium hydroxide solution (12.5 grams of sodium hydroxide to 1,000 cc of water) were added.

The sample was allowed to digest 15 minutes in a water bath maintained at 85° C. The sample when cooled was filtered through paper pulp and made up to a volume of 500 cc. Two aliquots of 50 cc each were removed for the determination of the nitrogen not precipitated by the copper hydroxide. The remaining 400 cc were divided into two equal aliquots and each evaporated to 100 cc for the determination of ammonia and amid nitrogen. Three cc of concentrated sulfuric acid was then added to each sample and hydrolyzed for 2 hours. The hydrolysate was made neutral with sodium hydroxide and then made alkaline with magnesium oxide. The total ammonia, which included the amids, was distilled off and titrated.

The nitrogen not precipitated by copper hydroxide minus the total ammonia nitrogen (ammonia plus amid) is defined here as "harmful" nitrogen.

EXPERIMENTAL RESULTS

Changes in weight, sucrose percentage, and coefficient of apparent purity for the 1937 field test are given in Table 1 and for the 1938 test in Table 2. A summary of the 1937 and 1938 results are also presented in Fig. 3. In both tests there was a continuous decrease in weight of roots as drying proceeded and, as would be expected, there was a continuous rise in sucrose percentage. It is important that there was a continuous decline in indicated available sugar yield. This is explained in part by the fact that the rate of loss in weight was greater than the rate of increase in sucrose percentage.

Delayed topping also resulted in striking changes in certain nitrogen fractions. The changes in soluble and harmful nitrogen in tests for these seasons are shown in Fig. 1. These determinations were calculated on the dry basis and the data therefore shows actual changes. By referring to Fig. 1 it is seen that a striking increase in soluble nitrogen and a somewhat parallel increase in harmful nitrogen occurred as a result of delayed topping. The harmful nitrogen content of the fresh beets from King City in 1938 was approximately double the harmful nitrogen found in the fresh beets in the 1936 and 1937 tests. Despite this high harmful nitrogen content in 1938, delayed topping caused a 24% increase over the initial value. Increases of 52 and 50%, respectively, in harmful nitrogen occurred in the beets in the 1937 and 1938 field tests. In Chino, where the average temperature at harvest was high, 89% of the total increase in harmful nitrogen took place during the first 3 days. The change in harmful nitrogen was not rapid in the tests conducted at King City. In these tests, little or no change in harmful nitrogen was noted the first day. It is apparent from Fig. 2 that a greater percentage of the soluble nitrogen appears as harmful nitrogen as delayed topping proceeds. The decrease in this ratio *at the beginning* of the experiment may be associated with the rise in coefficient of apparent purity for the same period.

SUMMARY

Field tests showed that a loss of sugar occurred as topping of the beets was delayed. Soluble and harmful nitrogen increased in the beets during the same period.

A greater percentage of the increase in soluble nitrogen appeared as "harmful" nitrogen as the period between lifting and topping increased.

TABLE 1.—*Results obtained in delayed topping experiments at King City, Calif., 1937.**

Period between lifting and topping in days	Mean root weight in pounds	Calculated acre yield of roots in pounds	Relative root weights, %	Sucrose %	Sucrose Relative %	Apparent purity coefficient	Calculated acre yield indicated available sucrose, pounds	Relative sucrose weights %
0	1.62±0.011	50,695	100.0	19.17±0.31	100.0	94.7±0.32	9,201	100.0
1	1.37±0.013	42,989	84.8	21.02±0.16	109.7	95.7±0.33	8,649	94.0
2	1.30±0.021	40,687	80.3	22.03±0.24	115.0	95.5±0.19	8,561	93.0
3	1.22±0.023	38,288	75.5	22.34±0.10	116.6	95.1±0.36	8,133	88.4
4	1.17±0.011	36,582	72.2	22.97±0.14	119.9	95.0±0.16	7,985	86.8
5	1.13±0.014	35,459	70.0	23.17±0.05	120.9	94.1±0.23	7,733	84.0
6	1.01±0.016	31,708	62.6	25.65±0.17	133.8	92.3±0.21	7,508	81.6
7	0.98±0.016	30,704	60.6	25.42±0.12	132.6	90.0±0.25	7,023	76.3

*Data for average root weights, sucrose percentages, and apparent purity coefficients as determined from samples are given together with the acre yields of roots and sugar calculated on basis of 100 per cent stand. Results are averages of ten 20-beet samples.

TABLE 2.—*Results obtained in delayed topping experiments at King City, Calif., 1938.**

Period between lifting and topping in days	Mean root weight in pounds	Calculated acre yield of roots in pounds	Relative root weights, %	Sucrose %	Sucrose Relative %	Apparent purity coefficient	Calculated acre yield indicated available sucrose, pounds	Relative sucrose weights %
0	2.03±0.019	63,576	100.0	16.15±0.30	100.0	86.5±0.70	8,877	100.0
1	1.94±0.032	60,948	95.9	16.34±0.19	101.2	87.1±0.58	8,670	97.7
2	1.78±0.019	55,801	87.8	16.93±0.13	104.8	88.0±0.32	8,314	93.7
3	1.69±0.017	53,069	83.5	16.91±0.18	104.7	86.6±0.42	7,775	87.6
4	1.56±0.024	48,895	76.9	18.32±0.13	113.4	88.6±0.58	7,940	89.4
5	1.47±0.022	46,166	72.6	18.55±0.19	114.9	84.9±0.42	7,273	81.9
6	1.33±0.017	41,775	65.7	18.80±0.12	116.4	84.6±0.64	6,644	74.8
7	1.25±0.021	39,110	61.5	19.21±0.31	118.9	87.9±0.57	6,603	74.4

*Data for average root weights, sucrose percentages, and apparent purity coefficients as determined from samples are given together with the acre yields of roots and sugar calculated on basis of 100% stand. Results are averages of ten 20-beet samples.

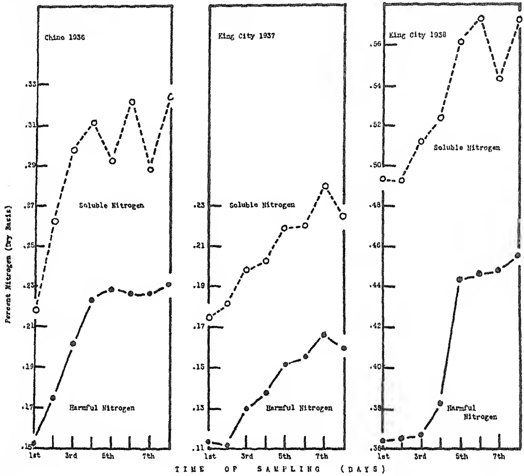

FIG. 1.—Changes in soluble and "harmful" nitrogen resulting from delayed topping of sugar beets.

The results clearly show for California conditions that the practice of lifting sugar beets several days in advance of topping results in a

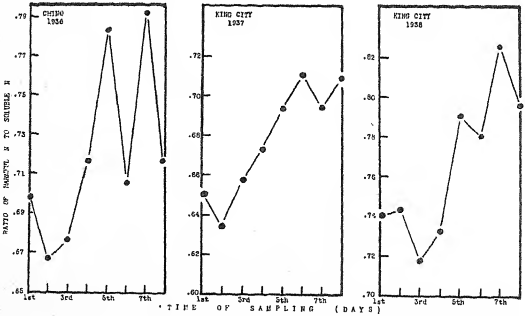

FIG. 2.—Changes in the ratio of "harmful" nitrogen to soluble nitrogen resulting from delayed topping of sugar beets.

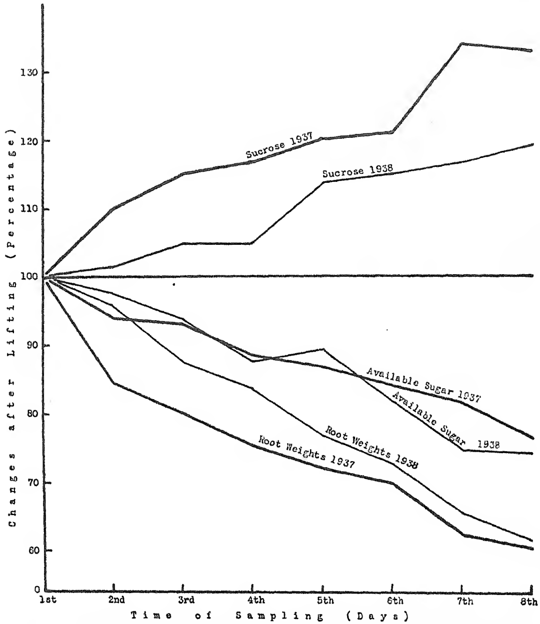

FIG. 3.—Changes in root weight, sucrose percentage, and yield of indicated-available sugar during periods between lifting and topping.

loss in sugar production. This loss is not only due to a direct loss in the field, but also to the increase in harmful nitrogen which would interfere with the recovery of sugar in processing.

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RELATION OF LEAF AREA TO GRAIN YIELD IN SORGHUM[1]

A. F. SWANSON[2]

LEAVES differ in size, shape, surface area, and number per plant among different varieties of sorghum. Early-maturing varieties generally have smaller and fewer leaves than late varieties. The number of leaves, as shown by Sieglinger (3),[3] varies with date of planting, locality, season, and other environmental factors, as well as with variety, and the length of the maturity period is increased from 2.8 to 3.5 days for each additional leaf a plant produces. The number of leaves is not constant for a variety, but for each variety there is a range of number of leaves produced that is fairly constant for a given environment.

Dwarf, short-stalked varieties may have as many leaves and as great a leaf area as tall varieties when both have the same or a similar range of maturity.

The purpose of this paper is to show the relationship of the leaf area of sorghum plants to grain yield and the response of leaf development to rainfall. The determinations were made at Hays, Kans., from 1929 to 1933.

MATERIALS AND METHODS

Leaf area determinations were made on plants of Dwarf Freed, Modoc, Custer, Kalo, and Dwarf Yellow milo. These five grain sorghum varieties were selected because they covered a rather wide range in time of maturity, height, leaf area, number of nodes, and length of internodes. The plants were grown in field plots by the usual methods with the spacing 6 inches apart in the row which was considered to be about the optimum for grain production under the conditions at Hays, except that milo generally responds better to a thinner stand.

About two weeks after full heading, but before any of the functioning leaves had dried or become torn by the elements, the sorghum stalks were cut several inches above the crown and taken to the laboratory. The leaves, without the sheaths, were stripped from the stalks and charted on paper with a pantograph. Later the leaf area was determined by a planimeter and calculated in terms of square feet per acre from the known number of stalks growing on 0.0424 acre plots. Leaf measurements were taken on three to six stalks of each variety each year. Both main and tiller stalks were used, since both types function in grain production. Only one surface of the leaves was considered as the measured area.

The leaves measured were only those still functioning and varied from 5 to 13 per stalk depending upon the variety. The small dried up leaves at the base of the stalks were discarded. Sieglinger (3) has shown that sorghum varieties similar to those studied at Hays may produce a total of 15 to 26 leaves. Usually, the lower 10 or 12 small leaves of the plants are covered by cultivation, are more or less disintegrated, or are so badly frayed by the elements before the active fruit-

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[3]Figures in parenthesis refer to "Literature Cited", p. 914

ing period that it is doubtful if they contribute materially to grain development. These small leaves which arise from the nodes at the base of the stalk serve the plants, however, during the seedling and early vegetative stages of growth.

The area of the leaf sheath was not calculated as a part of the leaf area. Miller (2) observed in 1914 that the exposed sheath area ranged from 6.0 to 12.4% of the combined leaf and sheath area for Dwarf Yellow milo, the higher percentage prevailing during the fourth and last stages of growth of the plants.

It has been reported that considerable photosynthesis can take place on the surface of the culms of wheat and photosynthesis doubtless occurs also in the leaf sheath of sorghums, but the extent has not been determined. However, in the more dwarf sorghums there is much over-lapping of the leaf sheaths which reduces the area fully exposed to light.

EXPERIMENTAL RESULTS

The number of functioning leaves for each stalk, the number per acre of plants, as well as the number of leaves required to produce 1 bushel of grain are shown in Table 1. Dwarf Freed which was the earliest variety to mature had the lowest number of leaves not only per stalk but on an acre basis. This variety required 6,504 leaves on an average to produce a bushel of grain. Kalo, on the other hand, required only 4,564 functioning leaves to produce an equal amount of grain and, from the standpoint of leaf number, was the most efficient of the varieties tested in grain production. Dwarf Yellow milo was low in efficiency, requiring 7,450 leaves to produce the same amount of grain as was produced by 4,564 leaves in Kalo.

The number of square feet of leaf surface required to produce a bushel of grain also is shown in Table 1. Kalo again was the most efficient, requiring only 1,463 square feet of leaf surface to produce 1 bushel of grain, while for Dwarf Yellow milo the area was 2,692 square feet. Dwarf Freed and Modoc also showed a high efficiency of leaf area to grain production, but on an acre basis these varieties had the lowest total leaf surface. The leaf size in these two varieties also was the smallest, the smallness of the leaves being associated with relatively early maturity. Custer had a relatively low leaf efficiency which may have been partly due to leaf competition for light because of dense foliage associated with very short internodes and dwarf plants.

The five varieties showed considerable variation in the number of functioning leaves per stalk. The average number ranged from 6.4 in Dwarf Freed to 10.8 in Dwarf Yellow milo.

Depending upon both variety and season, each leaf per stalk accounted for a grain yield of about 2 to 9 bushels per acre with an average of about 4.5 bushels under the conditions of the experiments. The average for the five varieties ranged from 3.5 to 6.0 bushels.

Sorghum varieties differ in their rate of transpiration. Miller (2) showed that Dwarf Yellow milo lost only 285.9 grams of moisture per hour from a square meter of leaf surface, while Freed sorghum, similar to Dwarf Freed, used in these experiments, lost 420.3 grams under the same conditions. This would indicate that the intensity of the transpiration is much greater per unit area in plants or varieties

TABLE I.—*Number of functioning leaves, leaf area, and grain yields of five sorghum varieties, Hays, Kans., 1929–33.*

Year grown	Height, ins.	Days to mature	Grain yield per acre, bu.	No. stalks per acre	Functioning leaves for each			Leaf area in square feet for each			
					Stalk	Acre of land	Bushel of grain	Leaf	Stalk	Acre of plants	Bushel of grain
					Dwarf Freed						
1929	44.0	102	49.3	45,821	6.5	297,837	6,041	0.263	1.710	78,353	1,589
1930	42.0	94	25.8	30,798	5.7	175,549	6,804	0.253	1.444	44,472	1,724
1931	49.6	92	31.6	26,715	7.1	189,677	6,003	0.348	2.470	65,986	2,088
1932	45.7	96	35.0	36,014	5.7	205,280	5,865	0.400	2.279	82,075	2,345
1933	40.2	90	29.4	32,780	7.0	229,460	7,805	0.091	0.636	20,848	709
Av....	44.3	95	34.2	34,426	6.4	219,561	6,504	0.271	1.708	58,347	1,691
					Modoc						
1929	52.7	109	59.1	47,667	8.7	414,703	7,017	0.285	2.479	118,166	1,999
1930	50.0	114	41.9	25,677	9.3	238,796	5,699	0.278	2.589	66,477	1,587
1931	49.1	102	36.0	26,904	8.8	236,755	6,577	0.262	2.303	61,959	1,721
1932	51.1	104	31.2	22,019	9.3	204,777	6,563	0.343	3.191	70,262	2,252
1933	47.7	107	33.7	23,175	12.0	278,100	8,252	0.094	1.133	26,257	779
Av....	50.1	107	40.4	29,088	9.6	274,626	6,822	0.252	2.339	68,624	1,668

						Custer					
1929	25.0	110	57.9	32,359	9.0	291,231	5,030	0.414	3.725	120,537	2,082
1930	34.0	122	23.0	21,570	10.7	230,799	10,035	0.378	4.045	87,250	3,793
1931	35.9	102	26.6	20,249	10.1	204,515	7,689	0.420	4.241	85,876	3,228
1932	37.2	115	43.6	23,506	10.3	242,112	5,553	0.453	4.669	109,749	2,517
1933	33.2	116	26.3	21,617	11.0	237,787	9,041	0.099	1.091	23,584	897
Av....	33.1	113	35.5	23,860	10.2	241,289	7,470	0.353	3.554	85,399	2,503
						Kalo					
1929	39.7	110	72.3	39,359	8.0	314,872	4,355	0.382	3.052	120,123	1,661
1930	47.5	124	47.8	23,930	8.0	191,440	4,005	0.456	3.646	87,248	1,825
1931	45.4	101	47.8	22,225	9.3	206,693	4,324	0.365	3.399	75,542	1,580
1932	45.5	115	59.0	30,468	8.0	243,744	4,131	0.406	3.251	99,051	1,679
1933	45.4	130	44.7	22,372	12.0	268,464	6,006	0.096	1.142	25,548	572
Av....	44.7	116	54.3	27,671	9.1	245,043	4,564	0.341	2.898	81,502	1,463
						Dwarf Yellow Milo					
1929	54.0	116	51.3	42,854	10.1	432,825	8,437	0.402	4.059	173,944	3,391
1930	43.5	133	40.6	18,927	9.7	183,592	4,522	0.433	4.199	79,474	1,957
1931	41.8	112	37.9	22,090	9.8	216,482	5,712	0.576	5.641	124,609	3,288
1932	61.4	112	52.9	33,346	11.3	376,810	7,123	0.508	5.742	191,472	3,619
1933	40.8	125	27.4	24,143	13.0	313,859	11,455	0.105	1.367	33,003	1,204
Av....	48.3	120	42.0	28,272	10.8	284,714	7,450	0.405	4.202	120,500	2,692

with small leaves. On a plant basis the transpiration was 181 grams for Dwarf Yellow milo and 124 grams for Freed. Early-maturing varieties, such as Freed or Dwarf Freed, do not have the potential yielding capacity of a late-maturing variety, such as Dwarf Yellow milo, but under dry seasons they can use a limited supply of moisture for more effective grain production. All late-maturing varieties tend to be abundantly supplied with large leaves and require the most favorable growing conditions for maximum grain yields.

RAINFALL AND LEAF AREA

A comparison of rainfall and leaf area is shown in Table 2. The leaf area was greatest, as might be expected, in 1929 and 1932 when there was an abundant moisture supply. The heavy leaf development in 1929 seems to have resulted from the heavy rainfall in July. The leaf area of milo that year was equivalent to four times the land area on which the crop was grown. The greatest vegetative development of the sorghum plant occurs just before the fruiting period. In Kansas, this heavy growth usually is during late July and early August if sufficient moisture is available. Other studies have shown that the plants cease to elongate after flowering begins.

The influence of drought on leaf development is shown by the results in 1933 when the rainfall was deficient throughout the growing season. The leaf area per acre was 73 to 81% less than in 1929 when there was abundant moisture and very heavy leaf development. However, the number of square feet of leaf area to produce a bushel of grain was much lower in dry years than in wet years. In Dwarf Freed it required 1,589 square feet of leaf area in 1929, while in the

TABLE 2.—*Rainfall in the growing season and leaf area.*

Year	Rainfall in inches				
	June	July	Aug.	Sept.	Total for four months
1929....	1.54	7.14	2.84	3.58	15.10
1930....	3.86	1.14	3.80	2.45	11.25
1931....	5.50	1.85	3.23	0.24	10.82
1932....	8.57	2.03	5.19	5.14	20.93
1933....	1.07	2.12	2.73	2.03	7.95

Year	Leaf area (in square feet) per acre					
	Dwarf Freed	Modoc	Custer	Kalo	Milo	Av. for five varieties
1929....	78,353	118,166	120,537	120,123	173,944	122,225
1930....	44,472	66,477	87,250	87,248	79,474	72,984
1931....	65,986	61,959	85,876	75,542	124,609	82,794
1932....	82,075	70,262	109,749	99,051	191,472	110,522
1933....	20,848	26,257	23,584	25,548	33,003	25,848

dry season of 1933 only 709 square feet of leaf area were necessary to produce a bushel of grain. For milo, the leaf area was 3,391 square feet per bushel of grain in 1929 but only 1,204 square feet in 1933.

DISCUSSION

The data presented indicate that early-maturing varieties having a small leaf area are the most efficient in the production of grain per unit of leaf area. Generally such varieties have a few small leaves well distributed along the stalks. In seasons of restricted rainfall such varieties tend to produce seed and reach maturity before the available moisture is exhausted. Later varieties have a higher daily transpiration and a longer transpiration period and are likely to suffer in dry seasons. In favorable seasons early varieties may yield well but are unequal to those of somewhat later maturity which have a greater leaf area and a higher potential yielding ability.

Certain very dwarf varieties, such as Custer, have an extremely dense foliage distributed over a limited stalk length due to much-shortened internodes. Such varieties seem to be handicapped to some extent from overcrowded leaves and consequent shading and reduced photosynthesis, even in years of abundant rainfall if the growing season is short. The degree of light intensity surrounding the leaves of varieties with dense foliage as compared with varieties in which the leaves are more widely separated was not determined in these experiments. However, Martin (1) has reported that within a given variety the height of a sorghum plant shows a high correlation with grain yield, and that conditions which favor elongation of the internodes of the sorghum stalk also favor an increase in the number and size of grain per head.

Dwarf varieties with dense foliage are often subject to greater injury from insects and fungus diseases. Many profusely-leafed dwarf hybrids have been observed at the Hays Station, but maximum yields have rarely been obtained from such types. On the other hand, leafy varieties, such as Dwarf Yellow milo and Double Dwarf milo, are rarely surpassed in grain yield if given a long season and an abundance of moisture, as under irrigation.

Sorghums which are intermediate in leaf development per plant and which have the leaves well distributed along the stalks are probably best able to meet the average dry land conditions prevailing in the Great Plains region. Kalo, a good representative of this type, has been one of the highest grain-producing varieties at Hays in years of normal rainfall but has been less productive than Dwarf Yellow milo under irrigation elsewhere. Pink kafir, Western Blackhull kafir, and Club kafir have plant characteristics similar to those of Kalo and are potentially high grain yielders at Hays.

SUMMARY

The leaf area per stalk of five varieties of grain sorghum differing in maturity, height, and size and number of leaves was measured during five consecutive years.

The total leaf area per acre ranged from about 21,000 to more than 190,000 square feet.

The average leaf area per stalk ranged from about 0.64 to 5.742 square feet, depending on the variety and season. The approximate requirement for the production of 1 bushel of grain was 4,000 to 11,400 leaves, having a total area of 570 to 3,800 square feet. Thus, for each leaf per stalk functioning during the fruiting period the grain yield was 3.5 bushels to 6 bushels per acre.

Abundant rainfall during the vegetative period stimulated leaf development. Less leaf area was required to produce a bushel of grain in a dry year than in a wet year, but the highest yields were obtained in seasons of abundant rainfall.

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THE EFFECT OF TILLERS IN CORN UPON THE DEVELOPMENT OF THE MAIN STALK[1]

C. E. Rosenquist[2]

THE tillers of corn plants are basal branches of the main stalk which retain a vascular connection with it throughout their life but develop an independent root system. It was the object of these experiments to determine the extent to which an interdependence for nutrients may exist between the main stalk and its established tillers. This was undertaken by subjecting tillers to four distinct treatments designed to exaggerate their behavior as true "suckers" or as contributors to the substance of the main stalk. These four treatments of the tillers consisted of (1) covering the tillers with burlap when about 3 feet tall to inhibit photosynthesis, (2) removal of tillers by pulling while small, (3) defoliation of tillers when about 3 feet tall, and (4) removal of earshoots from tillers at the silking stage.

The literature bearing on the subject of tillering of corn has been reviewed up to 1931 by Dungan.[3] He found that tillers will nourish a defoliated main stalk but that excessive tillering in fertile fields causes the main stalk to suffer materially in dry weather. Since publication by Dungan, Jones, *et al.*[4] report tillers as advantageous to sweet corn yields.

EXPERIMENTAL METHODS

Plants of common Nebraska dent field corn with a tendency to prolific tillering were grown in one-plant hills spaced 7 feet apart in both directions. This wide spacing was designed to remove plant competition and thereby facilitate full development of the plants differing in degree of tillering or treatment. Normal check rows were grown alternately with rows receiving the various treatments. Plant weights were taken on a moisture-free basis.

Those tillers whose photosynthetic activity was to be curtailed after attaining a height of 3 feet were enclosed in large burlap bags held in place on the north side of the plants by posts driven into the ground. Preliminary experiments had shown that tillers covered in this manner receive a negligible amount of light and turn yellow but live at least a month after covering. For the test involving defoliation of the tillers the leaf blades were cut off at the ligule.

The three seasons during which these tests were made were fairly normal for plant growth as reflected by a mean ear yield of 214 grams per main stalk of the untreated check plants and an ear yield of 156 grams for its tillers.

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[2]Associate Professor of Agricultural Botany. The author wishes to express appreciation for the advice and criticism given by Dr. T. A. Kiesselbach in preparing the manuscript and for the facilities of the Agronomy Department of the University of Nebraska necessary in carrying on the field work.

[3]Dungan, George H. An indication that corn tillers may nourish the stalk under some conditions. Jour. Amer. Soc. Agron., 23:662–670. 1931.

[4]Jones, D. F., Singleton, W. R., and Curtis, L. C. The correlation between tillering and productiveness in sweet corn crosses. Jour. Amer. Soc. Agron., 27:138–141. 1935.

RESULTS

The mean results of the various tiller treatment tests obtained during the three years, 1931–33, are presented in Table 1. The data for the various treatments are in terms of the normal untreated check plants as 100%.

TABLE 1.—*Effects of various tiller treatments upon the comparative grain and stover development of the corn plant, 3-year averages, 1931–33.*

Characters studied	Treatment of tillers				
	Check	Covered with burlap	Re-moved early	Defoliated	Ear shoots removed at silking
Mean number plants	—*	107	99	33	37
Entire plant:					
Total weight, %	100	48	45	49	87
Stover weight, %	100	80	36	48	106
Ear weight, %	100	33	57	51	72
Main stalk:					
Total weight, %	100	66	89	82	120
Stover weight, %	100	70	87	84	117
Ear weight, %	100	59	90	80	122
Tillers:					
Total weight, %	100	21	0	15	52
Stover weight, %	100	40	0	22	101
Ear weight, %	100	1	0	2	0
No. of main stalk ears, %	100	86	88	85	114
No. tiller ears, %	100	2	0	5	0

*Ten to 20 more check plants than treated plants in direct comparison.

Where the tillers were covered to prevent photosynthesis, they clearly became parasitic with their photosnythetic activity curtailed by excluding light. They drew upon the main stalk for their subsistence to such an extent that the main stalks were reduced 34% in weight and their ears 41%. The tillers themselves showed a 60% reduction in stover weight and 99% in ear weight. This treatment resulted in a 52% reduction in total plant weight.

These data on early removal of tillers show a consistent decrease of about 10% in total ear and stover weight of main stalks of treated plants, when compared with the untreated. This decrease may have been due to the fact that young tillers originate in the main stalk and no doubt draw on it for nutrients until they become fully established.

When tillers were defoliated at a height of 18 inches and leaf growth was kept down completely thereafter, they commonly remained alive until the whole plant matured. They were almost universally barren, however, producing only 2% as much grain as the tillers of normal untreated plants. Under this condition of virtual parasitism of the

tillers, the stover and ear yields of the main stalk were reduced 16 and 20%, respectively. The total plant, stover, and ear weights were reduced about 50% by defoliation of the tillers.

Removal of all tiller ears at silking resulted in increasing the total, stover, and ear weights of the main stalk about 20%. Stover weight of the tillers remained about the same as for the untreated tillers, but total weight and ear weight of the entire plant were reduced 13 and 28%, respectively. In the absence of ear shoots to which elaborated substances could be transported most of those substances were evidently removed from the tillers to the main stalk and de-eared tillers increased the size of main stalk ears over those of untreated plants.

SUMMARY

Tillers and main stalks of growing corn plants interchange water, foods, and nutrients.

When tillers of plants were covered with a layer of burlap to exclude light and prevent photosynthesis, both main stalks and tillers developed poorly, the treated plants weighing only 50% as much as untreated adjacent plants. Under these conditions, tillers depend upon the main stalk for their very subsistence and as a consequence dry weights of both main stalks and tillers were greatly reduced.

When tillers were removed early, the main stalks produced about 10% less dry matter than those of untreated plants.

Removing the leaves of tillers forced the tillers to become almost wholly dependent upon the main stalk.

The weight of the main stalk and its ear size were materially increased by removing the ear-shoots from the tillers at the time of silking.

Under conditions of wide spacing necessary in this study, removing or defoliating the tillers reduced the total weight of the plant at least 50% and the ear yield more than 40%.

COMPARATIVE AVAILABILITIES OF ORGANIC AND INORGANIC PHOSPHATES AS SHOWN BY THE NEUBAUER METHOD[1]

Franklin E. Allison, L. A. Pinck, and Mildred S. Sherman[2]

PREVIOUS studies (3, 7)[3] of the behavior of several water-soluble organic phosphates added to soils indicated that these phosphates do not possess markedly superior advantages over inorganic phosphates so far as their ability to penetrate soils is concerned. In most cases the organic phosphorus was removed from the soil solution, particularly in the heavier soils, nearly as quickly as was soluble inorganic phosphorus and hence would have little chance to penetrate to the deeper soil layers. The present paper reports evidence on the availability or toxicity to plants of several of these organic phosphate compounds. A number of inorganic phosphate materials were also used in these tests for comparative purposes.

METHODS

The Neubauer semi-quick method (6, 9) was chosen for these studies. Although this plant method was originally developed for the determination of fertilizer deficiencies in soils, it also serves as a useful tool in the study of phosphate availability and phosphate fixation by soils. It may also show toxicity of a given material or its decomposition products. In carrying out these investigations the detailed procedures, as described by Thornton in his bulletin (9) and in private discussions, were followed with a few exceptions noted below.

Thornton stresses the necessity for conducting the Neubauer tests at a constant temperature of 20° C. To meet this requirement a small room 4x5 feet in size and 6 feet in height was constructed in the basement with double walls and ceiling, and containing a thick layer of mineral wool for insulation. A bench was installed that provided adequate room for 45 Neubauer dishes, a large bottle of distilled water, scales and a hygrothermograph, leaving space for the worker. Both a refrigerator cooling unit and a 1,500-watt heater, controlled by a mercury thermoregulator, were installed beneath the bench. The air in the room was circulated by means of two fans blowing against the cooler. The compressor, circulating pump, and relay were outside of the constant temperature room.

Experiments (9) have shown that the Neubauer method gives essentially the same results whether the rye seedlings are kept in the dark or exposed to diffuse light. However, in the absence of light, the plants have unusually long, weak stems and tend to lodge, making the handling of the dishes more difficult. Our room was therefore provided with three 50-watt Mazda lamps distributed over the ceiling and controlled by an electric time clock located outside of the room. These were lighted for 12 hours each day.

Since the room was provided with both refrigeration and heating units it could be operated during either winter or summer with a maximum temperature variation of less than 1° C. The largest variations occurred, of course, during the short

[1]Contribution from the Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington, D. C. Received for publication June 16, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 925.

periods when the dishes were being weighed and watered. The room and all accessory equipment proved to be unusually satisfactory for the purpose designed.

The various organic and inorganic phosphates studied are given in the tables and in Fig. 1. Usually, the tests were conducted with quartz sand, Norfolk sandy loam (pH 5.1), and Chester loam (pH 4.8), but Cecil clay loam (pH 4.8) and Las Vegas loam (pH 8.4) were used in a few cases. The clay contents of the soils are as follows: Norfolk sandy loam, 6.3%; Chester loam, 31.6%; Cecil clay loam, 47.2%; and Las Vegas loam, 11.6%. These soils are described more fully elsewhere (3, 7). All experiments were run in triplicate using amounts of the various phosphates equivalent to 10 and 25 mg of P_2O_5. Potassium and nitrogen were added to all soils in the forms of potassium chloride and urea, respectively. Each culture received 25 mg of each of these elements.

Analytical data and other information concerning the organic phosphates, including the empirical formulas, have been recorded elsewhere (7). The analyses of the inorganic phosphates[4] are given in Table 1. Since the solubility and particle size of the inorganic phosphates may have some bearing on their availabilities and since the solubility of a number of these is to some extent dependent upon the method of preparation, the following information is given:

TABLE 1.—*The phosphoric acid content of inorganic phosphates.**

	Total P_2O_5, %	Citrate insoluble P_2O_5, %
Monocalcium phosphate, A.O.A.C. 1936, No. 1......	56.76	0.00
Dicalcium phosphate, No. R-100..................	40.90	0.00
Tricalcium phosphate, A.O.A.C. 1939, No. 2........	40.95	17.03
Hydroxyapatite, A.O.A.C. 1939, No. 3.............	41.97	31.98
Calcined phosphate, Ser. No. 1478................	37.25	3.73
Sodium metaphosphate........................	69.61	0.00

*The numbers of the various phosphates are those given to them by K. D. Jacob.

The mono- and dicalcium phosphates were C.P. grade materials and were ground to pass a 40-mesh sieve.

The tricalcium phosphate was prepared by slowly adding ammonia to a slurry of monocalcium phosphate and calcium sulfate in the proper amounts. The product was dried at 40° C and ground to pass an 80-mesh sieve (8).

Hydroxyapatite (calcium hydroxyphosphate) was prepared by the method described by Ross and Rader (8). The product was dried over P_2O_5 and ground to pass an 80-mesh sieve.

The calcined phosphate (defluorinated phosphate) was prepared by heating Tennessee brown-rock phosphate at approximately 1,400° C and the product ground to pass an 80-mesh sieve (4).

The soluble form of sodium metaphosphate was prepared by slowly heating sodium acid phosphate to 300° C until all the water was driven off, and then the heating was continued for some time at 500° C.

The method of planting the rye seeds used by Thornton, which involved the vertical placing of each seed in the sand with germ end downward, was not fol-

[4]The metaphosphate was kindly supplied by S. L. Madorsky and the other phosphates by K. D. Jacob of the Division of Fertilizer Research, U. S. Dept. of Agriculture. We are also grateful to them for giving us the information concerning the preparation and properties of these inorganic phosphates.

lowed. Instead, the mixture of 100 grams of soil and 50 grams of sand was first levelled with a metal disk that just fitted inside the culture dish. A tube soldered to the center of this disk facilitated the operation and provided an opening through which the glass tube, used in adding water, was placed in position. The 100 rye seeds were than laid on the soil-sand mixture and gently pressed into it with the metal plate. After removing the plate, 250 grams of sand were added and levelled with the disk. This procedure made certain that every seed was in intimate contact with the soil and thoroughly and uniformly moistened, an obvious necessity to insure uniform germination. The method proved to be more convenient and just as satisfactory as that used by Thornton.

The phosphorus content of the seedlings was determined colorimetrically by King's (5) method, after first oxidizing the organic matter with perchloric acid.

RESULTS AND DISCUSSION

The availabilities of the various inorganic and organic phosphates as plant nutrients in quartz sand and in soils are presented in Tables 2 and 3 and in Fig. 1. The data in the tables are, with few exceptions, the average values of triplicate tests using both 10 and 25 mgs of P_2O_5 per dish. Fig. 1 shows the combined average values for the two rates of application. The plots, therefore, represent averages of six replicas. In discussing these data it is convenient to consider simultaneously the comparative results for all of the phosphates in a given

TABLE 2.—*Availabilities of inorganic phosphates as found by the Neubauer method in sand and soils.*

Phosphate	P_2O_5 added, mg*	Percentage of added phosphorus taken up by plant in†				
		Quartz sand	Norfolk sandy loam	Chester loam	Cecil clay loam	Las Vegas loam
Monocalcium phosphate	10	76	66	17	14	66
	25	73	67	23	23	54
Dicalcium phosphate	10	47	77	19	—	—
	25	49	76	24	—	—
Tricalcium phosphate	10	21	44	29	—	—
	25	18	40	31	—	—
Hydroxyapatite	10	11	13	10	—	—
	25	12	12	9	—	—
Calcined phosphate	10	36	63	34	—	—
	25	30	54	30	—	—
Sodium metaphosphate	10	79	53	4	—	—
	25	71	64	9	—	—

*The average P_2O_5 content of the unfertilized seedlings grown on quartz sand was 28.4 mg per vessel, on Norfolk sandy loam 28.2 mg, on Chester loam 28.0 mg, on Cecil clay loam 26.7 mg, and on Las Vegas loam 29.8 mg. One hundred seeds contained an average of 28.6 mg of P_2O_5.

†The variations in these data did not exceed ±3% for 56% of the cases, and ±7% for 90% of the results.

soil or sand since the availability of a given phosphate varies markedly with the medium in which the plant is grown.

TABLE 3.—*Availabilities of organic phosphates as found by the Neubauer method in sand and soils.**

Phosphates	P_2O_5 added, mg	Percentage of added phosphorus taken up by plant in				
		Quartz sand	Norfolk sandy loam	Chester loam	Cecil clay loam	Las Vegas loam
Sodium glycerophosphate	10	78	84	33	23	47
	25	71	74	33	21	58
Calcium hexose diphosphate	10	58	55	7	—	—
	25	48	60	14	—	—
Sodium nucleate	10	84	55	17	—	—
	25	79	71	16	—	—
Nucleic acid	10	79	45	4	—	—
	25	66	47	10	—	—
Dipotassium phenyl phosphate	10	52	51	5	—	—
	25	54	48	15	—	—
Potassium diphenyl phosphate	10	73	79	30	—	—
	25	57	53	25	—	—
Dipotassium diphenyl pyrophosphate	10	67	63	12	—	—
	25	65	56	14	—	—
Calcium ethyl phosphate	10	74	75	36	—	—
	25	65	76	35	—	—
Calcium diethyl phosphate	10	50	58	42	23	31
	25	40	52	38	20	26
Triethyl phosphate	25	3	4	3	—	—

*See footnotes to Table 2.

QUARTZ SAND EXPERIMENTS

In a pure sand which has a negligible adsorptive capacity, the availability of a given phosphate as a plant nutrient is largely determined either by its solubility or by the readiness with which it continues to yield phosphate ions to the plant. By reference to Fig. 1 it will be noticed that 75% of the phosphorus in monocalcium phosphate and sodium metaphosphate, which are readily soluble in water, was assimilated by the rye seedlings during their short growth period. The two water-insoluble compounds, hydroxyapatite and tricalcium phosphate, released only 11% and 20%, respectively, of their phosphorus to the plants. Dicalcium phosphate and calcined phosphate (defluorinated phosphate), as expected, gave results intermediate between the water-soluble and water-insoluble materials.

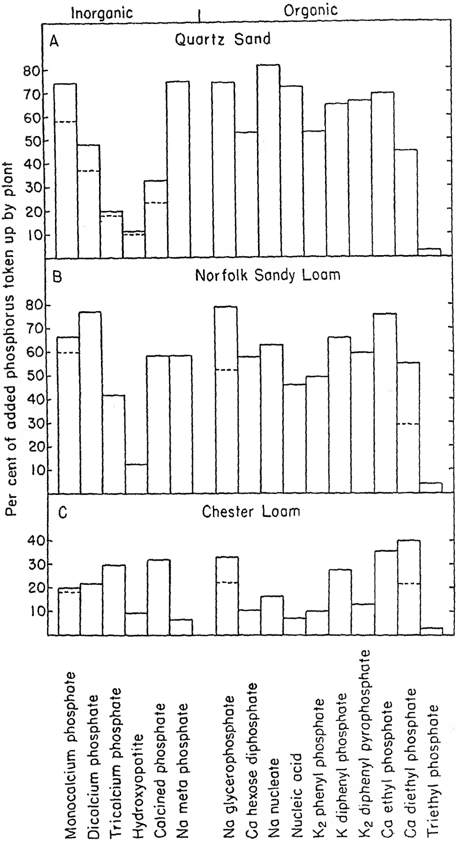

FIG. 1.—Availabilities of phosphates as shown by the Neubauer method. The dotted lines in section A refer to values obtained by Thornton (9) in quartz sand and in sections B and C to values obtained in the present studies on Las Vegas and Cecil soils, respectively.

The dotted lines in section A of Fig. 1 show the corresponding results obtained by Thornton (9) with similar materials. The agreement is quite satisfactory considering the large number of factors that would affect the two sets of experiments done by different workers.

The recovery of the phosphorus by the plant varied between 45 and 81% for all of the organic phosphates, with the exception of triethyl phosphate. Evidently all of these other phosphates readily gave phosphate ions to the rye seedlings. Two of the materials, namely, nucleic acid and calcium ethyl phosphate, are not water soluble but the phosphorus is nevertheless very available. Nucleic acid is undoubtedly readily attacked by microorganisms and the phosphorus converted into the inorganic form. Our previous studies (7) showed that in soils disodium ethyl phosphate was quickly converted into the inorganic form and the calcium salt would probably behave similarly. All of the organic phosphates, therefore, with the exception of triethyl phosphate, showed availabilities in quartz sand closely comparable to those of soluble inorganic phosphates. The uptake of phosphorus from triethyl phosphate by the rye seedlings was negligible. In our chemical studies (7) it remained unaltered and completely soluble in soil solution for a period of 3 weeks. Conrad (1), however, reported that this phosphate was retained to a certain extent by Yolo and Aiken soils and was toxic to plant growth.

The satisfactory recovery of phosphorus from nine of the ten organic phosphates studied does not signify, however, that they are satisfactory fertilizers. In quartz sand, dipotassium phenyl phosphate was decidedly toxic. With an application of 10 mg of P_2O_5, the roots and seeds were darker than usual; while with 25 mg of P_2O_5, the roots showed a limited development and both the roots and seeds were dark brown. This marked toxicity caused considerable variations in the Neubauer results but did not prevent fair recoveries of the added phosphorus. The toxicity may be accounted for by the extensive hydrolysis of the phenyl phosphate with the production of phenol. Diphenyl phosphate and diphenyl pyrophosphate, as previously shown (7), hydrolyze rather slowly and the amounts of phenol formed with an application equivalent to 10 mg of P_2O_5 were insufficient to show any toxicity. However, a moderate degree of toxicity was observed with 25 mg of P_2O_5.

NORFOLK SANDY LOAM EXPERIMENTS

In this soil dicalcium phosphate, tricalcium phosphate, and calcined phosphate showed higher availabilities than in quartz sand. The two water-soluble phosphates, especially sodium metaphosphate, showed somewhat lower availabilities than in the quartz sand. In general, the average availabilities of the organic phosphates were similar to those observed in the quartz sand experiments and varied between 46 and 79% recovery, exclusive of the triethyl phosphate which again was unavailable as a source of phosphorus. The recovery of phosphorus from the four most available inorganic phosphates varied between 59 and 77%. Dipotassium phenyl phosphate was toxic at both rates of application, whereas diphenyl phosphate and

diphenyl pyrophosphate were somewhat toxic at the higher rate only, as in the quartz sand experiments.

CHESTER LOAM EXPERIMENTS

The availabilities of practically all of the inorganic and organic phosphates in the Chester soil were much lower than in either the sand or the Norfolk soil. This soil has a pH of 4.8 and is of a fairly heavy texture with 31.6% clay and 41.1% silt. As shown previously (7), it retains phosphates very tenaciously against water extraction. Evidently from the results shown in Fig. 1 this retained phosphate is held so firmly that even plants are unable to use it to supply their full needs rapidly. Monocalcium phosphate and water-soluble sodium metaphosphate, which yielded 75% of their phosphorus to rye seedlings grown in quartz sand, furnished only 20 and 7%, respectively, of their phosphate to seedlings in the Chester soil. In this phosphate-fixing soil the very slightly soluble tricalcium phosphate and calcined phosphate gave significantly better results than the other materials, but the highest average recovery of the added inorganic phosphate was only 32%.

The organic phosphates other than the unavailable triethyl phosphate gave results on the average not very greatly different from those obtained with the inorganic phosphates. The recoveries varied between 7 and 40%, with an average value of 21% for the nine phosphates. This is almost exactly the same average value as that for the five inorganic phosphates other than the unavailable hydroxy-apatite. Evidently, much of the phosphate that the previous chemical studies (7) showed is nonextractable with water soon after the addition of the phosphate materials to soils, quickly becomes fixed so tenaciously that it is not readily available for plant use.

CECIL CLAY LOAM EXPERIMENTS

The only organic fertilizers tested in this soil were sodium glycerophosphate and calcium diethyl phosphate in comparison with monocalcium phosphate. The results are shown by the dotted lines in section C of Fig. 1. Both organic materials gave phosphate recoveries of about 22% which was only slightly higher than the value obtained for monocalcium phosphate. In comparison with results for Chester loam, discussed above, it will be noted that the Cecil loam held the added organic phosphorus even more tenaciously. The latter is, of course, high in clay content and is known as a phosphate-fixing soil to a greater extent than the Chester loam. This idea is the result of common practical observations using inorganic fertilizers and is in harmony with the experiments of Gile (2). The present results show that the Cecil soil is also a phosphate-fixing soil when organic phosphates are used.

LAS VEGAS LOAM EXPERIMENTS

The few experiments conducted with this calcareous soil (pH 8.4) are shown as dotted lines in Fig. 1, section B. Sodium glycerophos-

phate and calcium diethyl phosphate gave recoveries intermediate between those obtained with the light Norfolk sandy loam, on the one hand, and the Chester loam and Cecil clay loams, on the other hand. This result is in harmony with expectations, considering that the Las Vegas soil is itself an intermediate soil with respect to texture. Apparently the alkalinity of the soil was not a very important factor in the recovery of phosphorus from the three materials studied.

SUMMARY

The availabilities of ten organic phosphates in comparison with common inorganic phosphate fertilizers were determined by the Neubauer method in quartz sand, Norfolk sandy loam, and Chester loam. A few phosphates were also tested in Cecil clay loam and Las Vegas loam. The organic phosphates studied were glycerophosphate, hexose diphosphate, nucleic acid and its sodium salt, monophenyl and diphenyl orthophosphates, diphenyl pyrophosphate, and monoethyl, diethyl, and triethyl phosphates. The inorganic phosphates used for comparative purposes were mono-, di-, and tricalcium phosphates, hydroxyapatite, calcined phosphate, and sodium metaphosphate.

In any given soil or sand all of the organic phosphates, with the exception of triethyl phosphate, showed availabilities similar to those of the common inorganic phosphates. Triethyl phosphate which does not hydrolyze in aqueous solution showed a negligible availability as a plant nutrient. The phenyl phosphates, particularly the monophenyl phosphate, were toxic in the lighter soils and at the higher concentration.

The results as a whole emphasize the prime importance of the soil itself in determining the ability of plants to utilize added organic and inorganic phosphates. Since, as previous results (7) have shown, most organic phosphates are fairly rapidly converted into inorganic phosphates, their behavior in plant nutrition studies is usually not markedly different from that of ordinary inorganic phosphates. In the case of both types of materials, a high content of colloid or clay, especially if iron oxides and aluminum oxides are abundant, leads to marked phosphate fixation.

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CORRELATION OF TOTAL DRY MATTER WITH GRAIN YIELD IN MAIZE[1]

JOHN SHAFER, JR., AND R. G. WIGGANS[2]

THIS paper is concerned with a correlation between the grain yield of maize (*Zea mays* L.) and the total dry weight of the plants. Several authors have demonstrated such correlation within a particular commercial strain (1, 2, 4),[3] but none has attempted to compare progenies of many different varieties as in the present paper. If such correlation can be demonstrated, amount of grain produced might be used in a silage corn breeding program as a preliminary test for dry matter production. The data presented were collected for other purposes over a period of years. They represent (a) single cross hybrids (F_1's) between assorted inbreds of three or more years of inbreeding, (b) double cross hybrids involving similar inbreds, and (c) top crosses between many inbreds and one commercial variety. Almost all of the inbreds were derived from strains of corn which were or are grown commercially in New York.

Yield data were obtained from field tests. Each cross was represented by four replicates, each one a row of 17 hills. In general, there were four plants to a hill. Suitable checks were provided, being grown either in continuation of the experimental rows or in parallel rows.

The various plants were harvested during the regular silage cutting period beginning on or about September 15. At this time most of the crosses were at the stage of development best suited for silage making. However, the earliest strains were too mature for satisfactory ensiling, and the latest strains too immature. At the time of cutting, the fresh weight of all the plants in each replicate was determined. Subsequently, a known sample was dried and its total dry weight and content of dry shelled grain determined. From such data the weight of total dry matter and of dry shelled grain were calculated for each row.

For the calculations in this paper each figure represents the average of four (or rarely three) replicates. The yields of the experimental plants were expressed either as percentages of the check or as gains over the check. The method of expressing yield is unimportant for the purposes of this report, however, because in calculating coefficients of correlation, and other statistics dependent on them, all units of measurement cancel out.

The first step in the analysis of the data was to graph them, plotting total dry weight against weight of dry shelled grain. A typical graph is reproduced in Fig. 1. There appears to be a positive association, probably linear, between grain yield and dry weight of plant.

Following such preliminary graphing, the coefficients of correlation were calculated by Ayre's method for single cross populations of

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[3]Figures in parenthesis refer to "Literature Cited", p. 932.

three different years, for double cross populations of four different years, and for one top cross population. The coefficients (r) obtained are presented in Table 1. It will be noted that, although r varies considerably, yet all values of r are of the order of magnitude of 0.7. Even for the smallest population, the odds are greater than 99:1. Therefore, it is extremely unlikely that such large "r" values would occur just by chance.

TABLE 1.—*Summary of r values.*

Type of cross	Year grown	No. of crosses	r
F_1	1928	166	0.8503
	1929	155	0.6046
	1930	103	0.8054
Double cross	1930	104	0.7179
	1932	168	0.7300
	1934	155	0.6633
	1938	56	0.6846
Top crosses	1936	169	0.6627
Total		1076	Av. 0.7249

For determining the significance of the differences between r's, r was converted to z and Fisher's (3) formula $\frac{z_1 - z_2}{\sqrt{\frac{1}{n_1-3} + \frac{1}{n_2-3}}} = t$ was used. Odds were determined by reference to Livermore's (5) modification of Student's "t" table. For obtaining the average of two or more r values, Fisher's formula $\frac{\Sigma[(n'-3)z]}{\Sigma(n'-3)} = \bar{z}$ was used. Each experimental value of r had first to be changed to z and $\bar{z}$ had to be changed again to r, this r being the weighted average of the r values.

There was no statistical difference between the extreme values of r for double crosses, nor between the two r values for F_1's grown in 1928 and 1930. Consequently, these two F_1 values were averaged and likewise the several double cross values. There was a significant difference between the average of the two high r values for F_1 and the low 1929 value, and also between the high F_1 values and the average double cross and top cross values. The low value for r for 1929 F_1 data is hardly significantly lower than the average value for double crosses, and there is no significant difference between the top cross and average double cross values.

Although r is of value statistically, it is sometimes difficult to show its value from the standpoint of practical plant breeding. As a further aid in the interpretation of these data a different sort of calculation was employed. The graphs mentioned earlier were divided into quadrants by lines perpendicular to the two axes. Each of the two lines was so located that it divided the points of the graph into

halves. The graph of Fig. 1 has been so divided into quadrants to illustrate the method. All graphs were drawn with grain yields on the ordinates and dry weights on the abscissae. The divisions into halves are quite arbitrary, the assumption being made that only those plants in the upper half on the basis of grain yield or dry matter production, or both, are worth further study. After making such a division into quadrants, the number of points in each quadrant was counted and

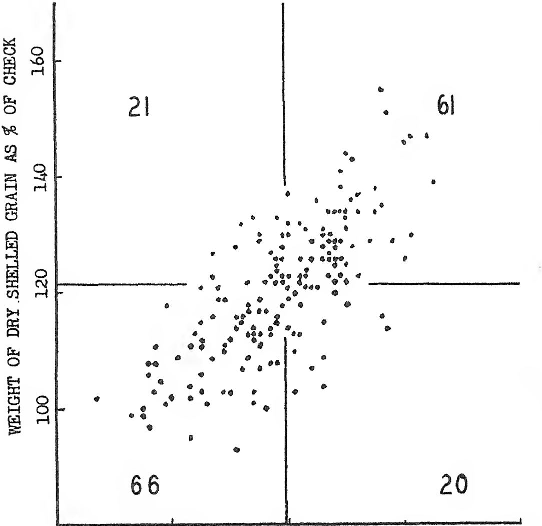

FIG. 1.—The relation between the weight of dry shelled grain and the total weight of dry matter. The data are those for double crosses grown in 1932. r = .7300.

expressed as a percentage of the whole. The results are given in Fig. 2. The counts are interpreted on the assumptions that grain yield is to be used as a test for dry matter, and that high dry matter is the character sought. On such a basis the plants whose yield data fall in the two right hand quadrants are the most desirable. Those in the upper right quadrant are saved by the "grain test", those in the lower right one are lost. Those plants represented in the upper left quadrant are

less desirable but cannot be eliminated by the "grain test." Those plants falling into the lower left quadrant are undesirable and are eliminated. A study of Fig. 2 indicates that a "grain test" for dry matter might be satisfactory in preliminary work. It appears that a "grain test" of this sort would reduce by one half the number of strains to be further tested, and of the half saved about 80% would be high in yield of both grain and total dry matter. Since grain yield is much easier to determine than is total dry weight, this method might provide a satisfactory and simple first year's test on a large number of crosses.

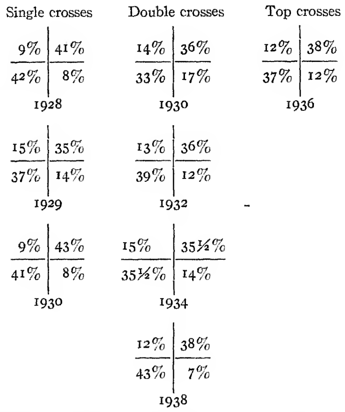

FIG. 2.—Figures showing the distributions of the populations of various crosses. The abscissae show weights of total dry matter; the ordinates weights of dry shelled grain.

An attempt to reduce below one half the number of strains to be used in advanced tests proved disappointing. The various graphs were divided anew by lines perpendicular to the axes, this time in such a way that each line divided the points of the graph into the best one-quarter and the poorest three-quarters. With such a procedure only about 16% of the plants are in the upper right quadrant. Unfortunately, the upper left and lower right quadrants are not much reduced; each retains about 10% of the total population. The lower left quadrant has about 65% of the total. Since the upper left and lower right quadrants contain almost as many points as the upper right one, it seems undesirable to make the divisions in this way. However, included in the upper right quadrant are about three quarters of the best 12½% (on the basis of dry matter), and if it is de-

sired to make a large reduction in the number of strains to be retested, such a separation on the basis of the 25% of the highest grain yielders might be used, even at the expense of losing some potentially valuable strains.

To employ such a "grain test" as is being described one must have a large heterogeneous population. In the course of the calculations one or two populations of about 30 strains each were found. They showed very poor correlation between grain and dry matter correlation. These data might be interpreted to indicate that this so-called "grain test" would not be suitable for small populations. One hundred might be arbitrarily considered as the minimum. One or two populations were studied in which a small group of inbreds was used repeatedly in crosses so that many crosses had one inbred parent in common. For some reason these populations showed very poor correlation, indicating that if the "grain test" is to be used at all it will be safer to apply it only to populations of heterogeneous origin.

There are three and perhaps many more possible causes for the correlation between yields of grain and total dry matter. In the first place, large plants have a greater leaf area than small ones and probably can synthesize more dry matter. It is reasonable to suppose that this greater synthesis of dry matter will result not only in a heavier plant but also in a greater accumulation of dry material in the grain.

A second explanation is based on work of Wiggans (6) and others showing a great increase in the total dry weight of corn plants coincidental with the growth of the ear and development of grain. Since all of the strains reported on here were harvested when the majority were suitable for ensiling, the grain was in general not fully mature. The early strains had the advantage of the post-flowering dry matter increase to a greater degree than the later ones. At the same time, being early, they had more mature grain and therefore a tendency to a higher percentage of grain in the total weight of dry matter.

Thirdly, there should be a tendency towards correlation of grain yield with total dry weight of plants, because the weight of the grain is included in the dry weight figure. The proportion of grain varies considerably, amounting in some cases to 50% or even more of the total weight of dry matter.

The operation of any of these three explanations would produce a tendency toward the correlation of the weight of dry grain with the total weight of dry matter.

SUMMARY

Data obtained during a silage corn breeding program have been utilized to demonstrate a correlation between the weight of total dry matter produced and the weight of dry shelled grain. Single crosses, double crosses, and top crosses have been investigated. Most of the populations studied involved 100 or more different crosses. The correlation coefficients were definitely significant for all of the larger populations; r varied from .60 to .85.

It is suggested that for a preliminary test in a silage corn breeding program a "grain test" might be useful.

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THE NITROGEN CONTENT OF *POA PRATENSIS:* ITS RANGE AND RELATION TO FLOWERING DATE[1]

J. T. SULLIVAN AND R. J. GARBER[2]

DURING studies of individual plants of Kentucky bluegrass, a survey of the range of variation in total nitrogen (crude protein) was made and certain relationships of the total nitrogen content to the date of flowering were noticed.

That young grass of all species is richer in protein than more mature grass and that the percentage of protein decreases regularly up to the stage of seed ripening is common knowledge. Henry and Morrison,[3] among many others, give data to support this. It should follow that late strains which have not proceeded as far to maturity as early strains should be higher in protein than early strains at any comparable date up to maturity. Evans and Thatcher[4] have shown that this is true with timothy.

Differences in composition between early and late flowering plants at other times than during the reproductive period have not been pointed out. In this paper are presented data concerning the range in composition of Kentucky bluegrass plants and the association of the date of flowering of an individual plant with its nitrogen content during flowering and at non-reproductive periods of its growth.

MATERIALS AND METHODS

The plants studied were from two sources. One, which may be designated as series A, consisted of 139 plants grown from commercial seed in the greenhouse and transplanted to the field in the spring of 1937 as individually spaced plants. Observations during flowering and collections for analysis were made of these plants in 1938. Slips were taken from them and established in pots, after which they were transplanted again to a different field. In addition, 18 were increased sufficiently to furnish three 3-foot rows. Observations of the flowering dates and collections for analysis were made in 1940. The initiation of anthesis is referred to here as flowering.

Another group of plants, designated as series B, was composed of 164 plants which had been isolated from sod plugs gathered in pastures in several states of the northeastern region but primarily in Pennsylvania. They had been placed in the field as individual plants in 1938. Flowering observations and collections for analysis were made during 1939. A selected group of 32 plants of the series B was used for greenhouse studies during the winter of 1939–40.

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[2]Physiologist and Director, respectively. Acknowledgments are due to O. N. Breivik, J. G. Conti, and A. G. Morin for assistance in the analyses.

[3]HENRY, W. A., and MORRISON, F. B. Feeds and Feeding. Madison, Wis. Ed. 18. 1923.

[4]EVANS, M. W., and THATCHER, L. E. A comparative study of an early, a medium, and a late strain of timothy harvested at various stages of development. Jour. Agr. Res., 56:347–364. 1938.

Replications were not present in the field except for a limited number of plants in series A, as stated, but both groups were part of a larger number of plants and were selected in a seemingly uniform soil area.

When the plants were cut for analysis they were carried immediately to a drying room and dried under a current of warm air. They were later ground and analyzed for total nitrogen by the Kjeldahl method which was modified by the use of salicylic acid to include nitrate nitrogen. The results are expressed as percentage of oven-dry weight. Any dead or diseased tissue was discarded before grinding.

EXPERIMENTAL RESULTS

SERIES A

The plants in series A were examined on May 27, 1938, during the flowering period and were classified individually as early, medium, and late. Leaves and culms were sampled for analysis the same day. A few days later the plants were mowed uniformly and allowed to grow until August 25 when the aftermath, consisting of leaves only, was gathered for analysis. Table 1 gives the range in nitrogen content found and the means for the three maturity groups with the standard errors of the means.

TABLE 1.—*The nitrogen content of series A of Poa pratensis plants for the year 1938.*

Nitrogen content	Maturity group and number of plants			
	Early, 39	Medium, 75	Late, 25	Total, 139
		Leaves of May 27		
Maximum, %	2.49	2.60	2.53	2.60
Minimum, %	1.38	1.44	1.63	1.38
Mean, %	2.02±0.04	2.10±0.02	2.13±0.04	2.08±0.02
		Culms of May 27		
Maximum, %	1.18	1.33	1.65	1.65
Minimum, %	0.74	0.92	0.90	0.74
Mean, %	1.01±0.01	1.09±0.01	1.27±0.04	1.10±0.10
		Leaves of Aug. 25		
Maximum, %	3.03	3.01	3.07	3.07
Minimum, %	1.89	1.99	1.92	1.89
Mean, %	2.47±0.04	2.57±0.02	2.64±0.05	2.55±0.02

Considerable variation exists within the groups. The mean values for the maturity groups increase from the early to the late. The differences between means for the leaves of May 27 are not significant. The differences between the means for the culms of May 27 are highly significant for all three groups. The differences between means of leaves for August 25 are significant for the early and medium groups and for the early and late groups.

During 1940, observations were taken of the date of flowering of as many of these plants as survived. After flowering was complete the

plants were mowed and collections of the aftermath were made on September 6. The data for the year are given in Table 2.

TABLE 2.—*The nitrogen content of series A of Poa pratensis plants on September 6, 1940, as related to the date of flowering.*

Date of flowering	No. of plants	Maximum % N	Minimum % N	Mean % N	Consolidation of dates into	Mean % N
June 5..	27	3.95	2.62	3.28±0.06	Early	3.19±0.06
June 6..	18	3.72	2.33	3.06±0.09		
June 7..	42	3.55	2.29	2.88±0.05	Medium	2.92±0.04
June 8..	28	3.84	2.52	2.96±0.07		
June 9..	15	4.21	2.65	3.53±0.11	Late	3.53±0.09
June 10.	4	3.90	3.12	3.53±0.16		
Total.	134	4.21	2.29	3.10±0.04		

Consolidations of dates have been made to give early, medium, and late groups. The mean nitrogen value of the late group is significantly higher than that of the medium group ($t=6.10$; 1.0% pt. $=2.63$). The late group is also significantly higher than the early group ($t=3.19$; 1.0% pt. $=2.66$). The medium group, however, contrary to results elsewhere, is lower than the early group ($t=3.94$; 1.0% pt. $=2.62$).

The correlation between the nitrogen content of the plants in September 1940 with that of the same plants in August 1938 was significant ($r=+0.287$; 1.0% pt. $=0.228$) but not marked. This correlation was obtained for the entire group of 134 plants. No correlation was found for the plants of a particular flowering date.

The classification of maturity given the plants in 1938 held closely for 1940.

The analyses of the 18 plants which had been planted in triplicate rows showed that a difference in nitrogen content existed between plants. The F value for differences between plants was 6.95 (1.0% pt. $=2.39$). The extreme values for percentage of nitrogen were 2.56 and 3.72.

SERIES B

Observations were taken on each plant in series B in 1939 for the date of emergence of the panicle and for the date of flowering. A close relationship was observed between the two sets of dates. Only the dates of flowering are considered. The plants flowered over a period of 13 days, although relatively few were outside a period of 6 days. The plants were mowed on July 8 and the aftermath was gathered on August 30. The data for this year are given in Table 3.

Consolidation into three groups of approximately equal size has been made. The medium group is higher in percentage of nitrogen than the early ($t=3.00$), the late is higher than the medium ($t=3.64$), and the late is higher than the early ($t=6.75$). All differences are highly significant (1.0% pt. $=2.62$).

During the winter of 1939–40, 32 selected plants were brought to the greenhouse. They represented eight high-nitrogen plants and

TABLE 3.—*The nitrogen content of series B of Poa pratensis plants on August 30, 1939, as related to the date of flowering.*

Date of flowering	No. of plants	Maximum % N	Minimum % N	Mean % N	Consolidation of dates into	Mean % N
May 22..	1	—	—	3.22		
May 23..	1	—	—	2.94		
May 26..	1	—	—	3.07	Early	3.32±0.04
May 27..	30	4.17	2.81	3.33±0.06		
May 28..	18	3.61	3.12	3.36±0.03		
May 29..	58	4.20	2.70	3.48±0.04	Medium	3.48±0.04
May 30..	19	4.09	3.24	3.66±0.07		
May 31..	19	4.20	3.17	3.70±0.06	Late	3.68±0.04
June 1...	14	3.97	3.16	3.65±0.07		
June 2...	3	4.04	3.36	3.72±0.20		
Total..	164	4.20	2.70	3.50±0.02		

eight low-nitrogen plants, each of an early and of a later flowering date. They were increased by cuttings and planted in pots in soil of medium fertility with four replications. They received natural daylight only. Emergence of the panicle occurred in only a few pots early in the winter and those shoots were removed. Leaves which were removed for analysis on May 10 represented the second cutting in 5 months' growth. The data are given in Table 4.

TABLE 4.—*The nitrogen content of a selected number of clones of series B of Poa pratensis grown in the greenhouse, May 1940.*

No. of clones	Basis of selection from field, 1939	Mean nitrogen content, %	Mean yield per pot, grams
8.............	Flowering May 27, high N	2.61±0.04	5.13±0.10
8.............	Flowering May 27, low N	2.54±0.03	5.12±0.11
8.............	Flowering May 31, high N	2.74±0.04	4.68±0.09
8.............	Flowering May 31, low N	2.64±0.04	4.87±0.08
16............	All high N	2.67±0.03	—
16............	All low N	2.59±0.03	—
16............	All flowering May 27	2.57±0.02	—
16............	All flowering May 31	2.69±0.03	—

The high-nitrogen plants (as classified in the field) were higher in nitrogen than the low-nitrogen plants of the same maturity group and the later plants were higher than the early. There were significant differences only between the late and early, as follows:

Between early high N and early low N, $t = 1.42$
Between late high N and late low N, $t = 1.82$
Between early high N and late high N, $t = 2.53$
Between early low N and late low N, $t = 2.01$

The 5.0% pt. for all is 2.00.

By consolidation of groups we find a significant difference between all 16 high-nitrogen clones and all low-nitrogen clones; $t = 2.23$

(5.0% pt. = 1.98). There is a higher significance between all 16 early clones and all late clones; $t = 3.22$ (1.0% pt. = 2.62).

The correlation between the mean nitrogen content of the clones in the greenhouse and their content in the field the previous summer was statistically significant; $r = +0.488$ (1.0% pt. = 0.449). This correlation coefficient was obtained by grouping all 32 clones together. It was not possible to demonstrate a correlation of significance within any one of the groups of eight clones, possibly because of the small number of clones.

A negative correlation was found between the yield (Table 4) and the nitrogen content of the 16 clones in the greenhouse ($r = -0.906$; 1.0% pt. = 0.449).

SUMMARY

Data are presented showing the range in variation of Kentucky bluegrass plants under a similar environment.

Late-flowering plants were higher in nitrogen than plants flowering only a few days earlier when studied (a) during the flowering period, (b) several months later in the aftermath stage, and (c) when clonal isolations were grown in the greenhouse.

Within one group of plants, studied two years on different pieces of ground, a small but significant correlation ($r = +0.287$; 1.0% pt. = 0.228) was found for the nitrogen content for the two years.

A small but significant correlation ($r = +0.488$; 1.0% pt. = 0.449) was found between the nitrogen content of plants in the greenhouse and that in the field for 32 clones representing extremes of flowering dates and composition in the field. A negative correlation between the nitrogen content and the yield of 32 clones in the greenhouse was highly significant ($r = -0.906$; 1.0% pt. = 0.449).

NOTES

APPLICATION OF BORAX PRODUCES SEED SET IN ALFALFA

IN an investigation of the extent of boron deficiency in North Carolina soils and crops, the writers have found many soils of the state to show generally low available boron content. The majority of soils examined ranged from 0.10 to 0.30 p.p.m. of available boron.

Growers of alfalfa in North Carolina have experienced for many years comparatively low yields due to both boron deficiency and poor initial stands with a steady diminution of the stand from year to year. The failure to maintain satisfactory stands can probably be associated in some measure with the low boron contents of the soils on which the crop is grown. These conditions have led to the abandonment of the growth of alfalfa by many farmers.

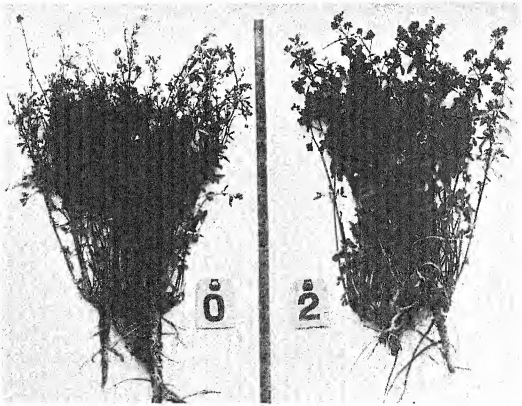

FIG. 1.—Seeding of alfalfa with boron. Left (0), four plants from no boron treatment, no seed; right (2), four plants from 20 pounds borax treatment, seeded.

An alfalfa planting in Caswell County[1] on a Cecil fine sandy loam, having a pH of 6.6 and an available boron content of 0.19 p.p.m. prior to boron treatment, showed severe boron deficiency symptoms during the 1940 season. A 20-pound application of borax was made to a section of this field in the late winter of 1941. Due to the spring

[1]The writers express their appreciation to J. E. Zimmerman, County Agricultural Agent, for his helpful cooperation in connection with this study; to the N. C. State Dept. of Agriculture for the germination data; and to the American Potash Institute for supporting the assistantship under which this work has been done.

drought, the usual first cutting was omitted. Blossoming occurred with little or no difference in the growth of the alfalfa between the boron-treated plot and the check plot, except for yellows on the no-boron area. Later, it was observed that a good seed set was being obtained where the boron had been applied (Fig. 1).

Analyses of the soil for available boron and of alfalfa hay for total boron content are as follows:

Untreated soil:
- Top soil, 0–5 in.—0.19 p.p.m. B
- Subsoil, 5–10 in.—0.18 p.p.m. B

Treated soil, 20 pounds borax per acre:
- Top soil, 0–5 in.—0.21 p.p.m. B
- Subsoil, 5–10 in.—0.25 p.p.m. B

Alfalfa:
- Untreated hay 4.80 p.p.m. B
- Treated (20 pounds borax per acre) hay 14.40 p.p.m. B

Germination of alfalfa seed was observed in the field where the seed had shattered on the soil. A sample of seed from the boron treatment gave a germination count of 76%; hard seed, 24%.

The failure of alfalfa to seed in many sections of the country has been attributed to adverse climatic conditions. While this is a factor in many sections, in this instance, where the alfalfa on the boron and no boron treatments grew under the same climatic condition, it is tenable to attribute the cause of a good seed set to the boron treatment rather than to climatic reasons. Work reported by various investigators shows that boron affects the seed set of many plants.

These observations suggest the possibility of growing commercial seed stocks of alfalfa and other plants not commonly grown in North Carolina for seed stock, because of their low yields, provided that the boron requirements of the plants are satisfactorily met on soils low in available boron.—J. R. Piland, and C. F. Ireland, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

THE ANCIENT HISTORY OF BORON DEFICIENCY SYMPTOMS

AGRICULTURAL research of the past 10 years has added immensely to our knowledge of what nutrients the growing plant needs, of what nutrients soils are able to supply, and of what nutrients must occasionally be supplied to soils. The significance of the so-called "minor elements"—minor only because of the small quantity which plants need—is becoming generally appreciated. The cordial reception given to publication by The American Society of Agronomy and the National Fertilizer Association of "Hunger Signs in Crops" portrays this present general interest in the subject. Yet since our knowledge of how certain of these crop disturbances may be controlled by the use of boron, zinc, copper, manganese, or other elements, is new, it has been thought by some that these deficiency diseases are themselves new. Some workers even assume that present recognition of these deficiency symptoms is necessarily related to

present extensive use of synthetically produced nitrogen fertilizers and increasing use of the purer and more concentrated grades of mixed fertilizers.

What are the facts bearing on such assumed relationship? To find the answer to this question we have but to search the literature bearing on this subject. A recent paper by Donaldson (6)[1] goes far towards providing the answer.

One of the "new" diseases of the apple is corky spot, a growth disturbance remedied by the use of boron and hence considered a symptom of boron deficiency. Burrell (2) has recently published on this subject. A quarter of a century ago, Mix (14) presented a paper entitled "Cork, Drought Spot and Related Diseases of the Apple"—unquestionably referring to the same disease. Even the plates used to illustrate the nature of the disease differ in no essential respect and could have been interchanged without harm to either publication. In his paper, published in 1916, Mix stated that "cork or drought spot" had even then been known and recognized for some 50 years. So in the use of boron we have simply a remedy for an old, old trouble frequently experienced.

Scarcely less impressive is the evidence as to black-heart disease of turnips. This disease is now generally recognized as a symptom of boron deficiency; and boron is recommended as a remedy in such widely distributed areas as England, Germany, Russia, New Zealand, Ontario, New Brunswick, Massachusetts, Maine, New York, and Virginia. It was only seven years ago that the first research evidence as to a relationship between the boron supply and the occurrence of black-heart was published by MacLeod (12); but the black-heart disease itself was described by Woods (18) in 1914—and Hurst (10) cites a parliamentary report made in 1910 on "brown-heart" of turnips—both dates being long before synthetically-produced nitrogen fertilizers were on the market or before our present concept of "concentrated fertilizers" had been developed.

Of similar nature is the heart rot of sugar beets. Here again boron is widely recommended as a remedy in such diverse places as Great Britain, Belgium, Netherlands, France, Germany, Italy, Switzerland, Sweden, Finland, Russia, Canada, Michigan, and Washington—with the first experimental evidence showing the relation between boron supply and occurrence of heart rot having been published by Brandenburg (1) in 1931. This publication may be considered the climax of over 35 years work since abortive attacks on the problem may be traced back from Gaumann (9) at Zurich in 1925, to Uzel (17) at Prague in 1911, to Kruger and Wimmer (11) at the Bernburg Experiment Station in 1909, to the investigations of Frank (8) of the Royal College of Agriculture in Berlin, published in 1896. So in the 35 years covering the recorded experience with "brown rot", this growth disturbance has been variously described as a bacterial disease ("*Phoma betae*"), as a physiological trouble (this expression in itself confessing ignorance as to cause), as a result of too heavy use of nitrate of soda or other alkaline-reacting material, and only recently as a result of a minor element deficiency. One wonders how much farther back

[1]Figures in parenthesis refer to "Literature Cited", p. 942.

practical experience went, but unfortunately the facts are not recorded.

The cracked-stem disease of celery is far less important—not to the individual growers but to the country at large—because of the much smaller acreage, but it is now recognized as a symptom of boron deficiency and is a growth disturbance remedied by the use of boron. Purvis and Ruprecht (16) published on this in 1937; the Florida Station (7) also published on the problem in 1924. The plates used for illustration were apparently the same, or at least identical in the sense that they were taken from the same original photograph even though used in two publications dated 13 years apart. What is now recognized as boron deficiency was not fully understood at the time of the early publication, but was thought to be associated with unbalanced fertilizer, climatic and moisture conditions, and also to an excessive use of lime.

Somewhat similar is the history of brown rot of cauliflower. The disease was known in the Catskill, N. Y., district ever since cauliflower growing became prevalent, according to Chupp and Horsfall (3), who report severe infections in 1918 and 1923, and again in 1933, with the loss of nearly a third of the crop due to the disease. Investigations by Dearborn, Thompson, and Raleigh (5) in 1935 showed that boron applications gave control, and later research has confirmed the diagnosis as boron deficiency. But two years of heavy infection in the Catskill area (1918 and 1923) preceded the appearance of synthetic and high-analysis fertilizers in this section, indicating that the boron supplied as an impurity in the older materials was not effective.

A search of the written record establishes the fact that these growth disturbances were recognized many years ago. The fertilizers of those early years were indeed different from those widely used today. Nitrogen from organic sources was used in larger proportions; nitrate of soda from Chile was widely used, with no competition from synthetically produced ammoniates and only moderate competition from by-product sulfate of ammonia; and the potash salts then in general use were of a lower K_2O content and contained more impurities than most of the commercial products of today. Superphosphate of the years before the war contained 14 to 16% available P_2O_5, instead of 20% and up, as typical of the present-day material. Even so, these minor element diseases are recorded as having occurred. This leads inevitably to the conclusion that many of these recorded disturbances reflected soil weakness which could not be remedied at the time by any soil treatment simply because the appropriate treatment was not known. This hypothesis is abundantly supported by recent developments. Shortage of boron has in fact been established in soil areas where little fertilizer, more particularly nitrogen, is used, or none is used at all, as in the case of alfalfa yellows in British Columbia (13), northern Idaho (4), and northwestern Oregon (15).

One is led, therefore, to the following conclusions:

1. There is nothing new in the fact of "minor element" deficiency difficulties.
2. What is "new" is the recognition of the meaning of deficiency symptoms and what is possible in the way of soil and crop treatment.

The fallacy, it seems, lies in assuming that the exhaustion of the minor element supply in the soil was or is due to the recent change in the fertilizer materials in common use, merely on the ground that this change happened sometime before the remedy for the deficiencies was discovered. It is an outstanding case of the time-honored *post hoc—ergo propter hoc* fallacy—concluding that because one event came before another, the first necessarily caused the second—an assumption disproved, at least as far as boron, in the case at issue, is concerned.

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—C. G. ATWATER, *The Barrett Company, New York City.*

TIFT BERMUDAGRASS, *CYNODON DACTYLON* (L.) PERS.[1]

TIFT Bermudagrass, to which No. F. C. 29716 has been assigned, was found in 1929 on an old cotton plantation near Tifton, Ga. It was mixed with common Bermudagrass over a small area about 2 rods square. When transferred to the Georgia Coastal Plain Experiment Station grass nursery, it soon became evident that rapidity of growth, hardiness, and heavy vegetative yield make this one of the

[1]Contribution from the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the Georgia Coastal Plain Experiment Station, Tifton, Ga.

most promising grass plants yet found for upland soils of the Coastal Plain of the Southeast. Apparently this grass is an unusual strain originating from common Bermudagrass.

The characteristics of Tift Bermudagrass readily identify it from common Bermudagrass. The stems are fine but with extremely long internodes. Leaves are long but narrow and usually form an acute angle to the stem. Propagation is made by rhizomes which are larger and easily distinguished from common Bermudagrass. As a pest in cultivated fields it could be equally as serious as common Bermudagrass, and control measures would require similar handling.

Tift Bermudagrass grows very rapidly and the individual plants at first appear too weak to stand upright, so the stems sprawl over the ground in all directions and many take root at the nodes. As the stand thickens the stems tend to be more upright and attain a height of 18 to 24 inches.

During dry seasons a few seeds are formed, but it may be considered a light seeder, which appears to be a reason for its heavy vegetative yield and long growing season. Single plants have spread over a radius of 10 to 12 feet in one season. No insect or disease damage has been observed.

As a hay producer, Tift Bermudagrass is showing much promise. When planted on Tifton sandy loam soil and fertilized with 600 pounds of 6–12–6 fertilizer per acre, three cuttings of hay in one season have given a 4-year average yield of 4,901 pounds of air-dried hay per acre. On another plot receiving the same treatment, except that 5 tons of stable manure were applied when the grass was set, the 4-year average yield of hay has been 6,081 pounds. Plots receiving small amounts of fertilizer have responded profitably to a 100-pound per acre top dressing of nitrate of soda after each of the first two cuttings.

It is desirable to cut the hay when the grass is around 12 inches high or before it becomes tough. Hay should be raked and shocked soon after cutting or the color is bleached out. Hay may be cured and baled in about 5 days after cutting.

As a grazing plant Tift Bermudagrass is superior to common Bermudagrass in carrying capacity and uniformity of grazing produced throughout the season.—J. L. STEPHENS, *Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture.*

BOOK REVIEW

HANDBOOK OF CHEMISTRY

Compiled and edited by N. A. Lange, assisted by G. M. Forker and R. S. Burington. Sandusky, Ohio: Handbook Publishers, Inc. Ed. 4. XVIII+1909 pages. Fabricoid cover. 1941. $6.

THERE are sections dealing with some 180 subjects in this excellent handbook in addition to the 271 pages of mathematical information. Six new sections have been added to the previous edition, namely, Properties of Cast Metals, Reduction of Barometer Readings, Symbols of Thermo- and Physico-chemical Quantities, Dimensional Formulas, and two tables on photographic films. All the data on molecular weights have been corrected for the 1940 atomic weights which also included a change in the molecular weight of hydrogen and thus affected most organic compounds.

There is such a wealth of information and so many useful tables in this handbook that those who use it a few times will regard it indispensible in the future. The mathematical section presents the subject with such clarity that it is being used as a text in several schools. A 35-page index of extremely clear construction makes orientation easy.

The reviewer searched the new edition in vain for weak points which could be criticised and is ready to admit that this handbook takes the place of several volumes on various subjects which were kept in readiness for the convenience of all who work in any branch of the natural sciences or technology. (Z. I. K.)

AGRONOMIC AFFAIRS

A TRIBUTE TO DOCTOR P. E. BROWN

THE July issue of the Iowa State College JOURNAL OF SCIENCE (Vol. XV, No. 4, 1941) is dedicated to the late Doctor P. E. Brown who, in addition to his other offices, served as Secretary and Treasurer of the American Society of Agronomy from 1920 to the time of his death except for 1932 when he was President of the Society. It contains a full-page photograph of Doctor Brown, an appreciation of his work by Doctor W. H. Stevenson, and a number of contributions in the fields of soil microbiology and soil fertility by workers, now elsewhere, who were either his colleagues or his students.

The authors and their topics are as follows: The Part Played by P. E. Brown in the Development of Soil Microbiology, by F. B. Smith; Soil Respiration Studies, by W. B. Bollen; The Plate Count Method, by N. James and M. L. Sutherland; The Influence of Organic Matter Decomposition on Some Alkaline Soils, by W. P. Martin and W. A. Kleinkauf; A Rapid Method for the Determinations of Soil and Plant Phosphorus, by W. R. Shelton and H. J. Harper; Studies on Seed Pea Production, by S. C. Vandecaveye and W. H. Fuller; The Numbering of *Rhizobia* Cultures, by L. W. Erdman; Iron and Phosphorus Solubility in Chlorotic and Non-chlorotic

Areas, by D. W. Thorne; Micro-organisms in Relation to Aggregate Size, by G. G. Pohlman and R. J. Nottingham.

Single copies of this issue may be obtained from the Collegiate Press Inc., Iowa State College, Ames, Iowa, for $1.00.

THE ANNUAL MEETING

THE thirty-fourth annual meeting of the American Society of Agronomy will be held in the Mayflower Hotel in Washington D. C., November 12, 13, and 14. Programs for the meeting may now be obtained from the office of the Secretary-Treasurer, Dr. G. G. Pohlman, Department of Agronomy, Agricultural Experiment Station, Morgantown, W. Va. Mimeographed abstracts of many of the papers to be presented in Washington may also be obtained from Dr. Pohlman upon payment of ten cents to cover handling and postage.

An Accommodations Committee has been named to aid those attending the meeting to find rooms. Inquiries should be addressed to Dr. A. G. McCall, Chairman of the Committee, Soil Conservation Service, U. S. Dept. of Agriculture, Washington, D. C.

NEWS ITEMS

THE FACILITIES of the Agronomy Department of the Iowa State College and the Farm Crops and Soils Subsections of the Iowa Agricultural Experiment Station at Ames have recently been improved by the erection of new greenhouses. Two units, each 100 × 35 feet, linked by a glass lean-to attached to a single story head-house, 120 × 16 feet, have been constructed. Provision has been made for the erection later of a third unit. The head-house contains rooms for soil mixing and storage, cold resistance and heat resistance equipment, and two laboratories. The greenhouse units are sectioned with a view to their use in investigational work in soil fertility and bacteriology, and plant breeding studies with small grains, forage crops, soybeans, and corn. Temperature control of each section is effected from a central panel. An unusual feature is the heating system, which is by overhead horizontal units each containing a slow speed fan. Distilled water for watering pots employed in fertilizer or nutritional studies is piped to all parts of the greenhouse, and is obtained by the distillation of rain water falling on the glass roofs and collected in a large cistern sufficient in capacity for many weeks supply.

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THE AMERICAN POTASH INSTITUTE of Washington, D. C., has issued in mimeographed form a "Bibliography of Literature on Potash as a Plant Nutrient" in which an effort has been made to review all literature on the subject from October 1, 1939, to March 31, 1940. The material is arranged in three sections, namely, crops, potash, and soils with sub-sections under each for place and author. A subject and author index is also included.

—A—

RECOMMENDATIONS for the fertilization of flue-cured tobacco grown on average soils in Virginia, North and South Carolina, Georgia, and

Florida for the year 1942 have been issued by the Agronomy Tobacco Work Conference of which Dr. C. B. Williams of the North Carolina State College, Raleigh, N. C., is Chairman and Dr. T. B. Hutcheson of the Virginia Agricultural Experiment Station, Blacksburg, Va., is Secretary.

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"REGENERATION OF NATIVE MIDWESTERN PASTURES UNDER PROTECTION" is the title of the most recent contribution (No. 23, June, 1941) to the Nebraska Conservation Bulletin published by the Conservation and Survey Division of the University of Nebraska. J. E. Weaver, Professor of Plant Ecology, and W. W. Hansen, Assistant Instructor in Botany, are co-authors of the paper.

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ACCORDING to an item appearing in the New York TIMES, seven sons of Professor E. J. Delwiche of the Department of Agronomy of the University of Wisconsin have passed through the College of Agriculture at Madison, and all but one who is in military service are engaged in agricultural work.

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ANNOUNCEMENT of the third general meeting of the American Society of Sugar Beet Technologists to be held at Salt Lake City, Utah, January 5 to 7, 1942, has gone out from the office of the Secretary-Treasurer, H. E. Brewbaker, Great Western Sugar Company, Longmont, Colorado.

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GEORGE D. THORNTON, formerly Instructor in Soils at the University of Georgia, has been appointed Assistant Professor of Soils and Assistant Soil Microbiologist at the University of Florida. Professor Thornton received the M.S. degree at the University of Georgia in 1939.

—A—

DR. LEWIS H. ROGERS, who has been away on leave for the past year working at Cornell University, has returned to the University of Florida as Associate Biochemist in the Soils Department.

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A COMPARISON OF HARDIGAN AND LADAK ALFALFA IN THEIR REACTIONS TO LEAFHOPPER INFESTATION[1]

S. T. DEXTER[2]

IN a study of the general adaptability of Ladak alfalfa in comparison with Hardigan for conditions in Michigan, made over a period of five years, the several sets of plots have afforded an opportunity for detailed observation of the damage done by leafhoppers. It has been a common observation in farming practice, and more particularly in field plot work in Michigan, that when part of an alfalfa field is cut a few days later than an adjacent area, heavy leafhopper infestation and yellowing may occur on the second growth of the plants in the early cut area, such damage being most severe on a narrow strip next to the later cut portion. Not infrequently it is virtually confined to a border strip 10 to 20 feet wide.

Throughout the five years of study of the comparative responses of Ladak and Hardigan alfalfa to different time-of-cutting treatments, the second growth on the border areas of early cut plots has been, to all appearances, equally infested with leafhoppers as evinced by the characteristic reduced growth and yellowed appearance of both varieties. As usual, Ladak was slower in recovery after cutting than was Hardigan. In these trials, the actual damage done by leafhoppers was largely confined to the second crop, was most intense on the borders of early cut alfalfa, but was not reflected in reduced stands on such border areas, in increased winterkilling there, or in reduced growth of the first crop the next season. In fact, such border areas, severely yellowed and stunted in one summer, were indistinguishable as regards stand and vigor of growth from the immediately adjacent alfalfa which had been cut later the previous season and had thereby escaped the more serious leafhopper attack.

In order to obtain additional evidence with respect to the recovery of the alfalfa or possible differential recovery of the two varieties, additional winterhardiness and root reserve studies were made on a series of plots in the winter of 1940–41, and yields were taken in June 1941 from the same plots.

[1]Contribution from the Section of Farm Crops, Michigan Agricultural Experiment Station, East Lansing, Mich. Journal Article No. 528 n.s. Received for publication May 16, 1941.

[2]Research Associate in Farm Crops.

In the area under consideration, three strips each of Ladak and of Hardigan alfalfa were seeded alternately (July 1939) to give six areas approximately 30 × 600 feet. Additional subdivision into 36 plots was made, each 30 × 100 feet. For the cutting management, each of these 36 plots was divided into three parts, *viz.*, A, B, and C, and was cut as follows:

Plot	Cut	Stage of bloom
A	June 17	Full bud to early bloom
	Aug. 15	Almost full bloom
	Nov. 4	Frosted
B	June 17	Full bud to early bloom
	Aug. 15	Almost full bloom
C	July 2	Full bloom
	Sept. 4	Full bloom

In the second growth of the early cut (June 17) alfalfa (A and B), strips adjacent to the later cut alfalfa turned yellow (1940 was an unusually bad "leafhopper year" at East Lansing). Since the width of the strip cut early was 67 feet, there was, in the center, a considerable area sufficiently removed from the late cut alfalfa that only slight yellowing occurred. Only slight yellowing was seen in the second growth of the late cut alfalfa (subplots C).

On January 6, 1941, root samples were taken from the margins of subplots A, from the relatively unyellowed areas of subplots B, and from subplots C. These roots were considered to be in a winterhardened condition. Ten main plots, five each of Ladak and Hardigan, were so sampled, giving 30 lots of roots, 10 each of A, B, and C. The diagram in Fig. 1 shows where the samples were taken.

The roots were taken to the laboratory, severed from the crowns, washed, and cut into pieces about 1 cm long. From each of the 30 lots of roots, two 10-gram samples were weighed out for the freezing—exosmosis determination of winterhardiness, each sample consisting of numerous 1-cm sections of the roots.[3] From each lot, one 5-gram sample was taken for the determination of dry matter and subsequent determination of available carbohydrates. Thus, 60 samples were used in cold resistance determinations and 30 for determination of available carbohydrates. Table 1 gives the results of the determinations of hardiness.

Each value given for the varieties is the average of 10 determinations, two samples from each of five replicate plots. Statistically, there was no difference between treatments A or B, nor between Ladak or Hardigan in any treatment. Treatment C gave roots somewhat less cold resistant than either treatments A or B. In Michigan this is in accordance with expectation, since cutting the first part of September is usually damaging in this vicinity no matter what the

[3]DEXTER, S. T., TOTTINGHAM, W. E., and GRABER, L. F. Investigations of the hardiness of plants by measurements of electrical conductivity. Plant Physiol., 7:63–79. 1932.

DEXTER, S. T. The winterhardiness of weeds. Jour. Amer. Soc. Agron., 29:512–517. 1937.

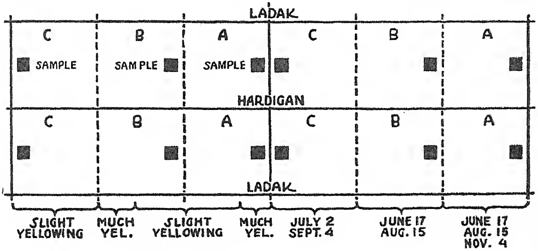

FIG. 1.—Diagram showing location of sampling areas.

previous treatment may have been. So far as cold resistance is concerned, the variation in leafhopper infestation does not seem to have been a controlling factor with either variety. This again is strictly in accord with previous experience. Yellowing is almost the rule near fence rows or at the margin of late cut and early cut areas; yet winterkilling is not correspondingly excessive in these infested spots, nor do they show up as inferior in growth the next year.

TABLE 1.—*Specific conductivities ($\times 10^6$, $2°C$) of solutions from roots of alfalfa plants exposed to various degrees of leafhopper infestation in which exosmosis occurred following freezing.**

Variety	Cutting treatment and infestation		
	Plot A, cut June 17, Aug. 15, Nov. 4; much yellowing	Plot B, cut June 17, Aug. 15; slight yellowing	Plot C, cut July 2, Sept. 4; slight yellowing
Ladak..........	2,038	2,022	2,617
Hardigan.......	1,898	2,018	2,457
Average........	1,968	2,020	2,537

*Frozen 4 hours at $-9°$ C; exosmosis 20 hours, $2°$ C, 50 cc of water.

The samples that were used in the determination of percentage dry matter were ground fine, mixed with water, boiled, and subjected to salivary digestion. The solutions were suitably filtered, cleared with lead, deleaded, hydrolyzed with acid, neutralized, and made to volume. Total sugars were then determined by the Bertrand method. Table 2 gives the values obtained in the determination of percentage dry matter and percentage total available carbohydrates (as glucose) on a green weight basis.

Each value given for a variety is the average of five determinations. As in the determination of cold resistance, there was no significant difference between the two varieties or between treatments A and B. Treatment C resulted in slightly lower available carbohydrates and dry matter than did the other two.

TABLE 2.—*Percentage dry matter and percentage total available carbohydrates (green weight basis) in roots of alfalfa plants exposed to various degrees of leafhopper infestation.*

Variety	Cutting treatment and infestation		
	Plot A, cut June 17, Aug. 14, Nov. 4; much yellowing	Plot B, cut June 17, Aug. 14; slight yellowing	Plot C, cut July 2, Sept. 4; slight yellowing
		Dry Matter	
Ladak	35.32	35.24	33.48
Hardigan	34.88	36.64	34.72
Average	35.10	35.94	34.10
		Available Carbohydrates	
Ladak	5.44	4.98	4.88
Hardigan	4.93	5.22	4.97
Average	5.19	5.10	4.93

In spite of the fact that Ladak alfalfa was materially slower in recovery from the first cutting than was Hardigan,[4] no difference in leafhopper injury could be observed in the field. Although this experimental arrangement of alternate strips of Hardigan and Ladak has been used for several years in combination with varied cutting treatments, neither variety has been observed to escape the marginal infestation of leafhoppers in years when the insects were plentiful. In the event of severe cases of "alfalfa yellows", the loss of much of the "second cutting" hay was involved, particularly at the margins of the plots.

On June 11, 1941, the hay on subplots A and B was harvested in early bloom, as in 1940. Across each subplot in the margin yellowed in the summer of 1940 a strip 6 feet wide was cut with a mower. In a similar manner a strip was cut through the area not severely yellowed. The green hay from these 144 areas was weighed promptly after cutting. Seventy-two of these areas were severely yellowed in 1940 and 72 were only slightly yellowed. Of each of the 72 areas, 36 were Ladak and 36 Hardigan. Although various mixtures of the alfalfas with grass were included in these plots, the data in Table 3 are presented in a condensed form as "yields of green alfalfa", since the same mixtures were made in each variety.

TABLE 3.—*Pounds of green alfalfa per plot (June 1941) following differential leafhopper yellowing in 1940.**

Variety	Much yellowing	Slight yellowing
Ladak	54.13 ± 1.1	55.03 ± 0.9
Hardigan	55.03 ± 0.7	54.33 ± 0.6

*Each figure is the average of 36 weights, each from approximately 1/250 acre.

[4]GRABER, L. F. Recovery after cutting and differentials in injury of alfalfa by leafhoppers. (*Empoasca fabae*) Jour. Amer. Soc. Agron., 33:181–183. 1941.

Although 1940 was a year in which yellowing was greater than usual in Michigan, the yellowed areas yielded as much hay per acre in 1941 as did the rest of the plot. Hardigan and Ladak show no statistical difference in their response to previous leafhopper infestation.

SUMMARY AND CONCLUSIONS

Hardigan and Ladak alfalfa have been grown in alternate strips over a period of five years in which time neither variety has shown resistance to leafhopper yellowing.

Studies of carbohydrate storage and cold resistance in January 1941 brought out no residual varietal differences following yellowing or lack of yellowing the previous year.

Yield measurements in June 1941 from areas severely yellowed (borders) or slightly yellowed (interior areas) in 1940 showed no varietal differences due to leafhoppers, nor were the border areas inferior in yield to equal areas in the interior of the plots.

The conclusion may be drawn in this experiment that, within the sensitivity of the technic employed, Hardigan and Ladak alfalfa reacted in a similar manner to leafhopper injury and to the general effects of cutting management. In neither variety did relatively severe leafhopper infestation occasion serious reduction in cold resistance, or in carbohydrate storage, or in subsequent yield of the plants; nor does such reduction appear likely under comparable conditions, provided cutting or grazing management is such that abundant organic reserves are stored before heavy freezes occur.

From the results of several experiments reported elsewhere and from numerous personal conversations with workers in several states other than Michigan, the author is forced to the additional conclusion that Ladak and Hardigan alfalfa and leafhoppers do not behave identically in any two states.

EFFECTS OF APPLYING COMMON SALT TO A MUCK SOIL ON THE YIELD, COMPOSITION, AND QUALITY OF CERTAIN VEGETABLE CROPS AND ON THE COMPOSITION OF THE SOIL PRODUCING THEM[1]

Paul M. Harmer and Erwin J. Benne[2]

MUCH work has been done in both Europe and America in an effort to determine the role of sodium in plant metabolism and its effect when used as a fertilizing constituent. The copious literature on the subject is reviewed by Willis (9).[3] The studies with sodium salts in Rhode Island, first begun by Wheeler and Adams (8) in 1894 and continued by Hartwell and his associates (3, 4, 5), are especially worthy of mention. Miller (6) gives a concise summary of the literature concerning the influence of sodium upon plants.

Numerous recent papers indicate a continued interest in the subject; hence the writers believe that a report of the results of studies begun by the senior author in 1924 and still in progress concerning the use of common salt as a constituent of fertilizers for crops grown upon muck soil, will be of interest. The term muck[4] as used in this paper refers to those soils which contain a very high content of organic matter in a more or less well-decomposed condition. Since muck soils as a class contain very small amounts of both sodium and potassium (2), opportunity to observe the effects of applications of these two constituents is correspondingly greater with them than with mineral soils. Inasmuch as Michigan contains several million acres of muck land (2), is one of the leading producers of celery and sugar beets which are shown in this study to be very responsive to salt, has 13 beet sugar factories well distributed over the state, and ranks first among the states in the production of salt (7), this study becomes one of considerable local economic importance.

EXPERIMENTAL

Although the effects of salt upon numerous crops have been investigated on a number of the muck areas of the state, the data reported in this paper were obtained largely from a series of plots known as the "salt series" (Fig. 1) in the muck

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[3]Figures in parenthesis refer to "Literature Cited", p. 979.

[4]Additional studies made on the more peaty types of soils show that the conclusions drawn in this study are applicable to all organic soils of Michigan.

experimental field on the college farm at East Lansing. This series of plots was arranged in an effort to answer several questions, *viz.*, Can sodium serve as a substitute for potassium in the fertilization of muck crops? How much salt can be supplied annually without injury to those crops which exhibit an initial benefit from its use? Is the marked benefit to these crops due to the sodium or to the chloride of the salt, or to both? Can a low-grade potash fertilizer,[5] such as Kainite, be used economically under Michigan conditions because of the benefit from its high salt content? At what time during growth does the assimilation of the salt occur? Is the continued application of the salt likely to have detrimental effects on the chemical or physical condition of the soil and on its ability to produce non-salt-responsive crops?

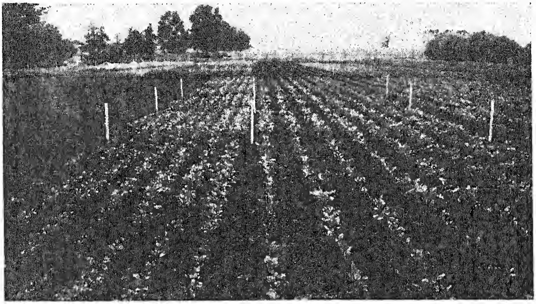

FIG. 1.—A portion of the salt series on the College muck plots with table beets on left and sugar beets on right of center. Plot 6, in immediate foreground, received 900 pounds per acre of 0–8–24. Just beyond first stakes, plot 5 received in addition 1,000 pounds per acre of salt; beyond second stakes, plot 4 received 900 pounds of 0–8–48 without salt; and beyond third stakes, plot 3 received 0–8–24 with 500 pounds of salt.

The muck experimental field originally supported a heavy growth of tamarack (*Larix laricina*). The land had long been cleared and had been used as pasture for many years. The muck on which the salt series is located is 10 feet or more in depth and has a pH around 5.8 in the plowed layer, dropping to about 5.0 in the second foot. The plowed layer is dark brown in color and fairly well decomposed, although containing considerable fiber and woody material. The underlying layers become quite peaty and are largely of sedge (*Carex*) origin.

The field was tile drained and broken in 1930, and plots 1 to 6, inclusive, of the salt series (Table 1) were established in 1932 on soil which had been summer fallowed in 1931 and had never been previously fertilized. Plots 7 to 12, inclusive, were established in 1933 on adjoining land which had received a 600-pound-per-acre application of 0–8–24 (50% K_2O) in 1932.

[5]Run-of-mine potash salts now produced at the Carlsbad, N. M., mines and containing more than 50% salt might be used as a source of both potash and salt when transportation charges warrant it.

The phosphate application has been made uniformly on all plots each year since they were established. Beginning with 1933, plot 12 received no potash, but the carry-over of potash from the 1932 fertilization showed some effect on the yields of some of the crops on this plot in 1933 and 1934. Plots 1, 6, 11, and 4 never have received a salt application, while plots 7 and 9 have received no salt except what was present as an impurity in the Kainite.

Both fertilizer and salt were applied broadcast on all plots and disked in. Copper sulfate was included in the fertilizer at the rate of 50 pounds per acre in 1932 and 25 pounds in succeeding years. One or more side dressings of sulfate of ammonia were made uniformly on all plots on celery and, in wet seasons as needed, on some of the other leafy crops. To take care of possible boron deficiency, boric acid was applied uniformly at the rate of 25 pounds per acre in 1937 and 1938. These studies were made on a practical field basis, using commercial potash containing some sodium chloride as an impurity.[6]

Since it appeared that chemical analyses might offer some explanation for the very marked increases in yield given by several crops as a result of the salt application and might also yield information about what happened to the applied salt and its effect on the intake of other nutrients, especially potash, analyses were made of several crops in 1937, 1938, and 1939. Samples generally were secured in the field at harvest time, so that the amounts of the constituents removed by the crop could be determined. Standard methods of analysis, largely those of the A.O.A.C., were used in determining the several constituents reported later in this paper.

RESULTS

Certain rather definite physical effects in the crops benefited have been observed in the field following the use of salt in the phosphate-potash mixture. These include an increased growth of both roots and tops; a smaller proportion of roots affected by damping-off and black rot; healthier, glossier leaves, which appear more resistant to the attacks of such diseases as leaf spot (*Cercospora beticola*) of beets (Fig. 2) and blight (*Septoria Petroselini appli*) of celery; and an improved keeping and eating quality in the case of celery. Resistance to disease might entirely prevent the occurrence of leaf spot in seasons of light infections and would delay its appearance several days in summers in which the infection was of epidemic proportions. The gloss on the leaves receiving salt suggests a greater secretion of wax on the leaf surface, which may account for the increased resistance.

Without potash (plot 12), salt produced a very poor, unhealthy root growth of table beets, sugar beets, and turnips. In early growth most crops looked well but generally suffered severely from damping-off and black rot and, by midseason, the tops had become chlorotic. Generally, however, the tops of these crops made a somewhat better growth than did the roots. In the absence of potash, salt failed to produce a satisfactory crop yield of any kind. (See Fig. 3.)

[6]Potash carriers used in these experiments and reported in Tables 1 to 11 included 20% Kainite (plots 7 and 9) and muriate of potash (plots 1 to 6, 8, 10 and 11) of the following analyses: 50% K_2O containing approximately 12% salt, used in 1932 and 1933, and 60% K_2O containing approximately 2% salt in 1934 and later years.

EFFECT UPON YIELDS AND COMPOSITION OF CROPS

When fertilized with adequate potash in these experiments on muck soil, yields of table beets, celery, Swiss chard, mangels, sugar beets, and turnips have been consistently increased by the use of salt, while those of celeriac, cabbage, kale, radishes, kohlrabi, and rape generally have shown some improvement. Of the other crops tried, asparagus, barley, broccoli, Brussels sprouts, carrots, corn, lettuce, oats, onions, parsley, parsnips, peppermint, potatoes,

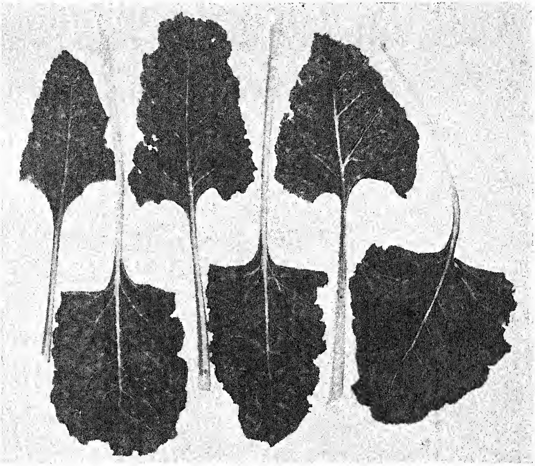

FIG. 2.—The upper three sugar beet leaves had been fertilized with 600 pounds per acre of a 0–8–24 mixture. The lower three leaves had received in addition to the 0–8–24 an application of 1,000 pounds per acre of ordinary salt. Note the healthier and more vigorous condition produced by the salt application.

spinach, and tomatoes have shown no benefit from the use of salt and some of them have sustained actual injury. Although all of the above-named crops have been grown in the field studies, brevity requires that the data presented in this paper concern only a few representative crops, principally those which exhibited benefits from salt applied in the fertilizer mixture. Although yields and analyses were secured from individual samples, space permits for the most part only a report of the averages for the crops.

Table 1 is a summary of from two to six years' data, showing the effect of ordinary salt applied as a fertilizing material on the yield of

table beets, turnips, celery, Swiss chard, and mangels. Table 2 gives a similar summary of the effect on the average yield, sugar content, and purity of sugar beets for a period of six years. Consideration of these data shows that salt, accompanying adequate phosphate, potash fertilization, has greatly increased the yields of all six crops.

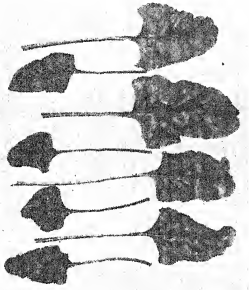

FIG. 3.—Table beet leaves from plots which received a uniform application of 600 pounds per acre of a 0–8–24 mixture. The plot which produced the small purplish leaves at the left received nothing else, while that which produced the healthy green leaves at the right received salt in addition at the rate of 1,000 pounds per acre.

Although in the early years of these trials, the 1,000-pound-per-acre salt application generally gave better yields of these crops than did the 500-pound application, in recent years the crops have sometimes shown as good or better yields with 500 pounds than with 1,000 pounds per acre. Kainite as a source of potash containing considerable salt as an impurity has consistently given much better yields of these crops than has the 50 to 60% potash carriers without salt, but the yields generally have not equalled those secured with the high-potash carriers plus salt. The control plots (1, 6, and 11) are significantly lower than all treatments except that of salt alone, which is significantly lower than the controls.

It is important that under these conditions salt has produced no decrease in the sucrose content or purity (Table 2) of the sugar beet roots, and, by increasing yields, has caused a marked increase in sugar produced per acre. Salt without potash (plot 12) has decreased the percentages of both sugar and purity. Table beets likewise have shown (data not presented) no appreciable change in sugar content and purity from the addition of salt to high phosphate-potash fertilizer mixtures but a considerable increase in total sugar per acre.

Tables 3 and 4 present averages of results from the 1937 and 1938 crops of sugar beets, roots and tops,[7] and of celery, respectively. They give the effect of varying salt and potash applications on the yield, as well as on the nitrogen, phosphate, lime, magnesia, soda, and potash contents of these crops, and on the amount of these constituents removed per acre.

When potash was also applied, the application of salt resulted in both crops in a decrease in nitrogen content of the dry and green

[7]In the harvest of sugar beets the crowns were cut from the rest of the roots as required by the sugar companies when the roots are delivered at the factory. Thus, the yields and analyses are of the roots with crowns removed and of the tops and crowns together.

TABLE 1.—*Effect of varying salt and potash applications to muck soil on the yield of several crops.*

Plot No.*	Fertilized annually, 1932–37, 600 lbs. per acre; 1938–39, 900 lbs. per acre	Salt applied annually, 1932–39, lbs. per acre	Average yield in tons per acre				
			Table beets	Turnips	Celery	Mangels	Swiss chard
			6 years, 1932, 1934, 1935, 1937, 1938, 1939	4 years, 1935, 1936, 1938, 1939	6 years, 1933, 1934, 1935, 1937, 1938, 1939	2 years, 1932, 1940	2 years, 1932, 1936
1, 6, 11	0–8–24	0	10.4±1.12	9.8±1.23	17.5±1.08	12.1±1.54	17.7±2.20
2	0–8–12	500	18.2±2.33	11.6±1.81	20.2±2.83	18.0	23.5
3, 8, 10	0–8–24	500	19.3±1.12	13.6±1.34	23.8±1.79	23.8±1.10	26.5±2.01
4	0–8–48	0	17.0±2.47	12.4±1.96	20.9±2.62	22.4	23.0
5	0–8–24	1,000	21.9±1.73	15.5±2.90	24.8±3.48	31.4	31.0
7, 9	0–8–24†	0	17.4±1.75	13.0±1.54	24.1±1.91	23.9	22.4
12	0–8–0	500	5.6±0.79	4.2±1.35	13.0±1.04	4.7	7.7

*Plots 7 to 12, inclusive, were not established until 1933. Averages of table beets, Swiss chard, and mangels include only plots 1 to 6 in 1932.
†Kainite.

TABLE 2.—*Effect of varying salt and potash applications to muck soil on yield, sugar content, and purity of sugar beets.*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938 and 1939, 900 lbs. per acre	Salt applied annually, 1932–39, lbs. per acre	Average for 6 years, 1934–39					
			Tons per acre		Sugar			Purity, %
			Roots (crowned)	Tops and crowns	Sucrose, %	Lbs. per acre		
						Total	Recoverable*	
1, 6, 11	0–8–24	0	7.8±0.56	9.6±0.82	15.2±0.38	2,373	2,031	85.6
2	0–8–12	500	10.6±1.18	13.2±2.31	15.4±0.76	3,265	2,737	83.8
3, 8, 10	0–8–24	500	12.1±0.79	14.0±1.49	15.8±0.40	3,843	3,305	86.0
4	0–8–48	0	11.3±1.38	11.0±1.75	16.2±0.63	3,680	3,215	87.5
5	0–8–24	1,000	12.3±1.43	13.1±3.03	16.3±0.67	3,998	3,403	85.1
7, 9	0–8–24†	0	11.8±0.96	13.3±1.78	16.1±0.46	3,785	3,271	86.4
12	0–8–0	500	3.2±1.08	8.2±1.17	10.2±1.38	660	443	67.2

*Recoverable sugar equals total sugar multiplied by per cent purity.
†Kainite.

TABLE 3.—*Effect of varying salt and potash applications to muck soil on the content of several constituents in sugar beets and removal by the beets.*

A, Pounds Per Acre Removed by Crop—Average 1937 and 1938

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Crop yield, tons per acre	Total moisture in crop, %	N	P_2O_5	CaO	MgO	Na_2O	K_2O
					Tops					
1, 6, 11	0–8–24	0	8.84	74.60	129.04	30.78	91.63	67.35	21.36	100.14
2	0–8–12	500	11.51	75.63	126.85	33.58	101.67	63.11	94.68	66.48
3, 8, 10	0–8–24	500	10.06	76.58	116.56	26.90	87.12	60.20	100.15	79.17
4	0–8–48	0	9.72	75.36	113.68	23.00	88.79	62.36	27.01	116.11
5	0–8–24	1,000	7.74	78.13	76.23	22.64	52.80	31.76	70.18	64.30
7, 9	0–8–24*	0	9.43	77.07	113.12	26.45	93.45	56.72	69.06	80.39
12	0–8–0	500	7.72	74.20	138.79	31.84	76.40	66.96	120.99	18.54
					Roots					
1, 6, 11	0–8–24	0	7.47	81.28	30.48	10.68	7.02	15.64	4.16	32.93
2	0–8–12	500	11.14	80.25	41.64	16.34	10.95	22.90	17.05	28.00
3, 8, 10	0–8–24	500	11.23	78.99	41.77	20.47	11.02	23.62	16.59	39.76
4	0–8–48	0	10.10	79.43	35.32	14.96	8.59	18.14	2.99	46.38
5	0–8–24	1,000	10.55	78.00	38.26	23.63	13.93	23.02	13.35	46.38
7, 9	0–8–24*	0	11.22	78.45	43.07	21.72	12.08	22.59	14.26	42.00
12	0–8–0	500	3.34	86.99	26.79	6.78	3.59	9.14	28.59	4.76
					Total crop					
1, 6, 11	0–8–24	0	16.31	77.66	159.52	41.46	98.65	82.99	25.51	132.74
2	0–8–12	500	22.65	77.90	168.49	49.92	112.62	86.01	111.73	94.48
3, 8, 10	0–8–24	500	21.29	77.85	158.33	47.37	98.14	83.82	116.74	121.30
4	0–8–48	0	19.82	77.43	149.00	37.96	97.38	80.50	30.00	162.49
5	0–8–24	1,000	18.29	78.06	114.49	46.26	66.73	54.78	83.53	110.68
7, 9	0–8–24*	0	20.65	77.82	156.18	48.17	105.53	79.31	83.32	122.39
12	0–8–0	500	11.06	78.06	165.58	38.62	79.99	76.10	149.58	23.30

B, Percentage of Constituent in Crop

Plot No.	Water-free basis						In green crop					
	N	P_2O_5	CaO	MgO	Na_2O	K_2O	N	P_2O_5	CaO	MgO	Na_2O	K_2O
						Tops and crowns						
1, 6, 11	3.15	0.747	2.15	1.60	0.53	2.43	0.777	0.187	0.551	0.406	0.135	0.614
2	2.59	0.655	1.99	1.29	1.88	1.35	0.646	0.161	0.487	0.320	0.463	0.335
3, 8, 10	2.73	0.623	2.03	1.39	2.12	1.79	0.646	0.147	0.478	0.328	0.487	0.419
4	2.74	0.564	2.11	1.45	0.60	2.80	0.682	0.142	0.523	0.356	0.147	0.699
5	2.45	0.724	1.75	1.01	2.12	2.22	0.540	0.160	0.388	0.224	0.462	0.495
7, 9	2.80	0.660	2.31	1.37	1.52	2.02	0.647	0.153	0.533	0.316	0.343	0.487
12	3.79	0.868	2.09	1.83	3.31	0.51	0.980	0.227	0.552	0.465	0.804	0.132
						Roots (crowned)						
1, 6, 11	1.12	0.391	0.340	0.564	0.173	1.23	0.210	0.073	0.142	0.106	0.033	0.229
2	0.97	0.388	0.258	0.516	0.452	0.66	0.190	0.076	0.138	0.102	0.088	0.129
3, 8, 10	0.90	0.443	0.244	0.499	0.401	0.89	0.188	0.093	0.051	0.105	0.084	0.187
4	0.86	0.369	0.223	0.424	0.073	1.20	0.177	0.076	0.046	0.087	0.015	0.248
5	0.84	0.506	0.315	0.478	0.315	1.01	0.185	0.111	0.070	0.105	0.070	0.222
7, 9	0.92	0.462	0.254	0.461	0.337	0.94	0.198	0.100	0.055	0.099	0.073	0.203
12	3.22	0.802	0.423	1.085	3.340	0.54	0.400	0.102	0.054	0.137	0.429	0.072
						Total crop						
1, 6, 11	2.19	0.568	1.35	1.137	0.349	1.82	0.489	0.127	0.302	0.254	0.078	0.407
2	1.68	0.497	1.13	0.860	1.118	0.95	0.372	0.110	0.249	0.190	0.247	0.209
3, 8, 10	1.68	0.501	1.04	0.889	1.237	1.29	0.372	0.111	0.230	0.197	0.274	0.285
4	1.67	0.425	1.09	0.899	0.337	1.82	0.376	0.096	0.246	0.203	0.076	0.410
5	1.43	0.574	0.83	0.684	1.040	1.38	0.313	0.126	0.182	0.150	0.228	0.303
7, 9	1.70	0.528	1.15	0.866	0.911	1.33	0.378	0.117	0.256	0.192	0.202	0.296
12	3.41	0.857	1.65	1.570	3.310	0.51	0.749	0.175	0.362	0.344	0.726	0.112

*Kainite.

TABLE 4.—*Effect of varying salt and potash applications to muck soil on the content of several constituents in celery, and removal by celery.*

A, Pounds Per Acre Removed by Crop—Average 1937 and 1938

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Crop yield, tons per acre	Total moisture in crop, %	N	P_2O_5	CaO	MgO	Na_2O	K_2O
1, 6, 11	0–8–24	0	23.04	90.67	109.21	35.94	200.91	23.50	35.48	126.26
2	0–8–12	500	29.21	92.22	113.33	43.82	146.05	21.62	193.37	96.98
3, 8, 10	0–8–24	500	30.91	91.85	118.08	40.18	185.46	22.26	188.55	141.57
4	0–8–48	0	27.14	91.08	111.82	37.45	185.64	22.25	55.37	254.57
5	0–8–24	1,000	34.39	93.85	95.60	45.39	164.38	17.20	190.52	149.25
7, 9	0–8–24*	0	31.77	91.88	119.46	41.30	196.34	20.97	167.75	144.87
12	0–8–0	500	13.26	91.01	83.27	37.39	75.05	17.77	128.09	17.50

B, Percentage of Constituent in Crop

Plot No.	Water-free basis						In green crop					
	N	P_2O_5	CaO	MgO	Na_2O	K_2O	N	P_2O_5	CaO	MgO	Na_2O	K_2O
1, 6, 11	2.55	0.840	4.66	0.555	0.83	2.96	0.237	0.078	0.436	0.051	0.077	0.274
2	2.48	0.973	3.22	0.470	4.29	2.12	0.194	0.076	0.250	0.037	0.331	0.167
3, 8, 10	2.30	0.778	3.62	0.432	3.69	2.76	0.191	0.065	0.300	0.036	0.305	0.229
4	2.31	0.769	3.89	0.463	1.13	5.26	0.206	0.069	0.342	0.041	0.102	0.469
5	2.03	0.949	3.46	0.358	4.03	3.15	0.139	0.066	0.239	0.025	0.277	0.217
7, 9	2.33	0.805	3.78	0.406	3.25	2.84	0.188	0.065	0.309	0.033	0.264	0.228
12	3.50	1.585	3.08	0.718	5.33	0.73	0.314	0.141	0.283	0.067	0.483	0.066

*Kainite.

material and in the total amounts removed per acre. The content of phosphate in the dry material (Table 3, B) appeared to have little correlation with the treatments in the sugar beet tops, but when salt was applied some increase was noted in the sugar beet roots and in the celery. The total phosphate removed by the crop when salt was applied was decreased in the tops and increased in the roots and total crop of the sugar beets and in the celery. The percentages of lime and of magnesia were decreased with the salt application in both tops and roots of the beets and in the celery. Salt decreased the total amount of both constituents removed by the beet tops and celery but increased that removed by the beet roots.

Addition of salt along with potash greatly increased in both beets and celery the percentage content of soda and the amount removed by the crop. It did not appreciably affect the percentage of potash in the dry material of the beet tops and celery but appeared to decrease slightly that in the beet roots. The amount of potash removed by the crop when salt was applied was slightly increased in the celery and beet roots but slightly decreased in the beet tops and in the total beet crop.

When salt was applied in the absence of potash (plot 12), the percentages of nitrogen, phosphate, magnesia, and soda in the dry material of celery and of beet tops and roots were increased and that of potash greatly decreased. The percentage of lime in the celery and in the beet tops was decreased but that in the beet roots was increased. With the exception of soda, none of these crops removed appreciably more of any of these constituents when salt was applied without potash.

Although an increase in the potash application in the absence of salt (plot 4) decreased the percentage of lime and magnesia in the dry material in both crops, it had little effect on the total amounts removed by the crops. Even though this high potash fertilization failed to give as much yield as did less potash applied with salt (plots 3, 8, and 10), the heavy potash resulted in an increase in potash removed in the crops of approximately 34% in the beets and 77% in the celery. In general, the effect of the Kainite application on the composition of the crops was intermediate between that produced by the high-analysis potash alone and the potash plus salt application.

Table 5 shows the effect of salt applications on the yields of the 1938 crops of table beets and turnips, on the 1939 crops of cabbage and onions, on the soda and potash contents of these crops, and on the amounts of these constituents removed per acre. Salt resulted in a marked increase in yield of table beets, both tops and roots, of turnip roots, and of cabbage heads but a decrease in yield of mature onions. In all four crops the application of salt has resulted in an increase in absorption of soda expressed either on the dry or green basis or in pounds per acre removed. Application of salt reduced the percentage potash in the table beets and onions, increased it in the turnips and cabbage, and increased the total potash removed in the beet, turnip, and cabbage crops but reduced it in the onions.

In the absence of a salt application (plots 1 and 4), an increase in

TABLE 5.—*Effects of varying salt and potash applications to muck soil on the content and removal of soda and potash by several vegetable crops.*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Crop yield, tons per acre	Total moisture, %	Percentage in crop				Pounds per acre removed by crop	
					Water-free basis		In green crop			
					Na_2O	K_2O	Na_2O	K_2O	Na_2O	K_2O
				A, TABLE BEETS, 1938						
				Tops						
1, 6, 11	0–8–24	0	5.34	84.24	1.16	3.75	0.177	0.584	18.57	62.31
2	0–8–12	500	7.46	85.36	3.43	2.68	0.502	0.392	74.93	58.54
3, 8, 10	0–8–24	500	7.30	86.36	3.12	2.99	0.426	0.408	61.99	59.52
4	0–8–48	0	5.25	86.35	1.24	5.40	0.169	0.737	17.78	77.41
5	0–8–24	1,000	5.65	84.73	3.44	3.58	0.525	0.546	59.33	61.75
7, 9	0–8–24*	0	6.59	84.79	2.65	3.31	0.405	0.505	53.22	66.12
12	0–8–0	500	5.20	83.78	4.72	1.02	0.766	0.165	79.62	17.21
				Roots						
1, 6, 11	0–8–24	0	14.91	91.93	1.49	4.82	0.116	0.376	34.51	112.26
2	0–8–12	500	22.91	93.66	4.53	2.53	0.287	0.160	131.55	73.47
3, 8, 10	0–8–24	500	21.85	94.01	4.36	3.54	0.262	0.211	114.83	92.17
4	0–8–48	0	16.85	92.97	1.66	7.10	0.117	0.499	39.32	168.18
5	0–8–24	1,000	22.74	92.95	4.57	3.62	0.322	0.255	146.48	116.03
7, 9	0–8–24*	0	20.69	93.34	3.94	4.02	0.262	0.267	108.34	109.76
12	0–8–0	500	7.14	93.71	4.78	0.90	0.301	0.057	42.95	8.07
				Total crop						
1, 6, 11	0–8–24	0	20.25	89.90	1.40	4.54	0.132	0.431	53.08	174.56
2	0–8–12	500	30.37	91.69	4.26	2.57	0.340	0.217	206.48	132.01
3, 8, 10	0–8–24	500	29.15	92.09	4.05	3.40	0.303	0.260	176.82	151.69
4	0–8–48	0	22.10	91.40	1.56	6.70	0.129	0.556	57.10	245.59
5	0–8–24	1,000	28.39	91.31	4.35	3.59	0.362	0.313	205.81	177.78
7, 9	0–8–24*	0	27.28	91.27	3.63	3.85	0.297	0.324	161.56	175.88
12	0–8–0	500	12.34	89.54	4.75	0.95	0.497	0.103	122.57	25.28

B, TURNIPS, 1938										
Tops										
1, 6, 11	0-8-24	0	16.38	90.94	0.87	2.27	0.079	0.206	25.75	67.45
2	0-8-12	500	14.70	91.39	2.51	1.94	0.216	0.167	63.53	49.10
3, 8, 10	0-8-24	500	14.38	90.96	2.31	2.68	0.208	0.242	60.00	69.42
4	0-8-48	0	15.04	91.64	0.56	4.69	0.047	0.392	14.19	118.02
5	0-8-24	1,000	13.36	90.95	1.79	3.87	0.162	0.350	43.29	93.60
7, 9	0-8-24*	0	14.35	90.79	2.10	2.40	0.193	0.221	55.74	63.49
12	0-8-0	500	3.44	88.05	4.49	0.77	0.536	0.092	36.91	6.33
Roots										
1, 6, 11	0-8-24	0	8.09	93.13	1.02	2.60	0.070	0.178	11.44	28.92
2	0-8-12	500	10.76	93.55	2.26	2.16	0.146	0.139	31.37	29.99
3, 8, 10	0-8-24	500	11.55	93.16	1.65	2.55	0.113	0.174	26.11	40.23
4	0-8-48	0	10.80	93.12	0.40	3.57	0.027	0.246	5.90	53.08
5	0-8-24	1,000	12.97	93.24	1.35	3.29	0.091	0.222	23.66	57.65
7, 9	0-8-24*	0	11.72	92.88	1.81	2.55	0.129	0.182	30.20	42.62
12	0-8-0	500	0.78	92.47	4.81	1.53	0.363	0.115	5.69	1.81
Total crop										
1, 6, 11	0-8-24	0	24.47	91.66	0.92	2.38	0.076	0.197	37.19	96.37
2	0-8-12	500	25.46	92.30	2.40	2.03	0.186	0.155	94.90	79.09
3, 8, 10	0-8-24	500	25.93	91.94	2.29	2.45	0.180	0.196	86.11	109.65
4	0-8-48	0	25.84	92.45	0.49	4.22	0.039	0.331	20.09	171.10
5	0-8-24	1,000	26.33	92.08	1.57	3.58	0.127	0.287	66.95	151.25
7, 9	0-8-24*	0	26.07	91.73	1.97	2.47	0.164	0.204	88.94	106.11
12	0-8-0	500	4.22	88.87	4.55	0.91	0.504	0.096	42.60	8.14
C, ONIONS, 1939, Bushels										
1, 6	0-8-24	0	1,017	92.80	0.049	1.64	0.004	0.125	2.28	71.18
2	0-8-12	500	821	93.60	0.107	1.56	0.007	0.100	3.22	45.96
3	0-8-24	500	895	92.73	0.135	1.61	0.010	0.117	5.01	58.61
4	0-8-48	0	871	93.11	0.037	1.83	0.003	0.126	1.46	61.42
5	0-8-24	1,000	914	92.81	0.209	1.52	0.015	0.109	7.68	55.80
12	0-8-0	500	143	93.38	0.583	0.63	0.039	0.041	3.12	3.28

TABLE 5.—*Concluded*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Crop yield, tons per acre	Total moisture, %	Percentage in crop: Water-free basis Na_2O	Percentage in crop: Water-free basis K_2O	Percentage in crop: In green crop Na_2O	Percentage in crop: In green crop K_2O	Pounds per acre removed by crop Na_2O	Pounds per acre removed by crop K_2O
				D, CABBAGE, 1939						
				Heads (untrimmed)						
1, 6	0–8–24	0	29.51	91.13	0.29	2.95	0.026	0.264	15.35	155.81
2	0–8–12	500	27.00	91.51	1.07	2.22	0.091	0.188	49.14	101.52
3	0–8–24	500	33.72	90.98	0.71	2.85	0.064	0.257	43.16	173.32
4	0–8–48	0	35.30	91.45	0.24	4.02	0.020	0.344	14.12	242.86
5	0–8–24	1,000	36.02	91.38	1.07	3.03	0.092	0.261	66.28	188.02
12	0–8–0	500	3.94	92.04	3.06	1.17	0.244	0.093	19.23	7.33
				Stumps (above ground)						
1, 6	0–8–24	0	2.07	86.01	0.58	3.78	0.082	0.529	3.39	21.90
2	0–8–12	500	1.55	88.12	2.37	2.53	0.281	0.300	8.71	9.30
3	0–8–24	500	1.80	85.92	1.11	3.61	0.156	0.508	5.62	18.29
4	0–8–48	0	1.82	84.58	0.30	4.28	0.046	0.660	1.67	24.02
5	0–8–24	1,000	1.63	86.02	1.39	3.33	0.194	0.466	6.32	15.19
12	0–8–0	500	1.09	91.63	4.38	1.10	0.367	0.092	11.67	2.93
				Total above ground						
1, 6	0–8–24	0	31.58	90.78	0.31	3.01	0.029	0.282	18.74	177.71
2	0–8–12	500	28.55	91.32	1.14	2.24	0.102	0.194	57.85	110.82
3	0–8–24	500	35.52	90.72	0.73	2.89	0.069	0.270	48.78	191.61
4	0–8–48	0	37.12	91.12	0.23	4.03	0.021	0.359	15.79	266.88
5	0–8–24	1,000	37.65	91.15	1.08	3.04	0.096	0.270	72.60	203.21
12	0–8–0	500	5.03	91.95	3.35	1.16	0.271	0.092	30.90	10.26

*Kainite.

TABLE 6.—*Effects of varying salt and potash applications to muck soil on the soda and potash contents of several vegetables.*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Percentage in crop									
			Total moisture, %	Water-free basis		In green crop		Total moisture, %	Water-free basis		In green crop	
				Na_2O	K_2O	Na_2O	K_2O		Na_2O	K_2O	Na_2O	K_2O
			KOHLRABI, 1938									
			Leaves					Balls				
1, 6, 11	0–8–24	0	84.89	0.38	2.56	0.056	0.387	91.03	0.278	4.67	0.025	0.419
2	0–8–12	500	86.14	1.20	2.26	0.166	0.313	90.46	0.930	3.93	0.089	0.375
3, 8, 10	0–8–24	500	86.63	0.96	2.56	0.136	0.352	90.63	0.563	4.55	0.053	0.427
4	0–8–48	0	85.65	0.20	3.15	0.028	0.444	89.90	0.129	5.00	0.013	0.505
5	0–8–24	1,000	86.25	1.12	2.55	0.154	0.351	90.13	0.772	4.13	0.076	0.408
7, 9	0–8–24*	0	86.50	0.82	2.75	0.110	0.372	91.10	0.528	4.85	0.047	0.432
12†	0–8–0	500										
			KALE, 1938					RAPE, 1939				
			Tops					Tops‡				
1, 6, 11	0–8–24	0	87.07	0.20	2.46	0.025	0.315	87.15	0.58	3.62	0.077	0.482
2	0–8–12	500	88.09	1.20	2.19	0.143	0.261	86.66	1.29	2.79	0.172	0.372
3, 8, 10	0–8–24	500	87.63	0.74	2.65	0.092	0.328	86.78	1.48	2.75	0.196	0.363
4	0–8–48	0	86.80	0.11	3.79	0.015	0.500	86.85	0.52	4.35	0.068	0.572
5	0–8–24	1,000	88.25	0.70	2.92	0.082	0.343	86.85	1.38	3.62	0.181	0.476
7, 9	0–8–24*	0	88.48	0.45	2.90	0.054	0.348	—	—	—	—	—
12	0–8–0	500	77.96	1.73	0.41	0.446	0.106	86.12	3.21	0.73	0.445	0.102

*Kainite.
†All plants on this plot died during growing season.
‡The rape on plots 7, 8, 9, 10, and 11 was not included in the analyses.

TABLE 7.—*Effects of time of harvest on the soda and potash contents of sugar beets, table beets, and asparagus.*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre; 1938, 900 lbs. per acre	Salt applied annually, 1932–38, lbs. per acre	Percentage in crop, 1938							
			Water-free basis				In green crop			
			Na_2O		K_2O		Na_2O		K_2O	
			Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
			SUGAR BEETS							
			Tops							
1, 6, 11	0–8–24	0	0.57	0.47	2.79	2.25	0.081	0.106	0.395	0.508
2	0–8–12	500	4.19	1.72	1.75	1.16	0.537	0.360	0.224	0.244
3, 8, 10	0–8–24	500	3.55	2.45	2.69	1.73	0.488	0.517	0.366	0.363
4	0–8–48	0	0.95	0.67	5.63	2.52	0.128	0.146	0.756	0.549
5	0–8–24	1,000	3.96	2.18	3.79	1.50	0.637	0.443	0.610	0.305
7, 9	0–8–24*	0	3.43	1.86	2.92	1.69	0.462	0.401	0.395	0.363
12	0–8–0	500	4.60	4.00	0.53	0.49	0.751	0.733	0.087	0.090
			Roots							
1, 6, 11	0–8–24	0	0.091	0.100	1.13	1.10	0.015	0.018	0.192	0.200
2	0–8–12	500	0.329	0.238	0.65	0.58	0.064	0.048	0.128	0.117
3, 8, 10	0–8–24	500	0.242	0.238	0.88	0.73	0.049	0.050	0.179	0.155
4	0–8–48	0	0.056	0.069	1.32	0.88	0.011	0.014	0.253	0.176
5	0–8–24	1,000	0.274	0.219	1.16	1.01	0.058	0.046	0.244	0.214
7, 9	0–8–24*	0	0.225	0.222	0.92	0.75	0.042	0.045	0.173	0.156
12	0–8–0	500	3.380	3.770	0.40	0.42	0.424	0.435	0.050	0.049

TABLE BEETS

Tops

1, 6, 11	0–8–24	0	0.74	1.16	3.47	3.75	0.090	0.177	0.421	0.584
2	0–8–12	500	4.61	3.43	2.39	2.68	0.457	0.502	0.237	0.392
3, 8, 10	0–8–24	500	4.09	3.12	2.90	2.99	0.447	0.426	0.316	0.408
4	0–8–48	0	1.15	1.24	4.24	5.40	0.137	0.169	0.503	0.737
5	0–8–24	1,000	4.49	3.44	2.97	3.58	0.571	0.525	0.378	0.546
7, 9	0–8–24*	0	4.04	2.65	2.87	3.31	0.469	0.405	0.341	0.505
12	0–8–0	500	5.00	4.72	0.47	1.02	0.681	0.766	0.064	0.165

Roots

1, 6, 11	0–8–24	0	0.49	1.49	2.88	4.82	0.055	0.116	0.319	0.376
2	0–8–12	500	2.83	4.53	2.29	2.53	0.283	0.287	0.229	0.160
3, 8, 10	0–8–24	500	1.94	4.36	2.76	3.54	0.195	0.262	0.276	0.211
4	0–8–48	0	0.54	1.66	2.87	7.10	0.058	0.117	0.308	0.499
5	0–8–24	1,000	2.22	4.57	2.82	3.62	0.221	0.322	0.281	0.255
7, 9	0–8–24*	0	2.08	3.94	2.91	4.02	0.195	0.262	0.273	0.267
12	0–8–0	500	5.62	4.78	0.52	0.90	0.448	0.301	0.041	0.057

ASPARAGUS

1, 6, 11	0–8–24	0	0.039	0.096	4.00	2.70	0.003	0.021	0.305	0.594
2	0–8–12	500	0.061	0.298	3.76	2.80	0.006	0.061	0.339	0.576
3, 8, 10	0–8–24	500	0.048	0.182	3.89	2.46	0.004	0.038	0.293	0.508
4	0–8–48	0	0.038	0.054	4.09	3.20	0.003	0.011	0.277	0.669
5	0–8–24	1,000	0.051	0.223	3.94	2.89	0.004	0.046	0.296	0.596
7, 9	0–8–24*	0	0.041	0.130	4.02	2.40	0.003	0.029	0.278	0.525
12	0–8–0	500	0.171	0.432	3.18	0.70	0.013	0.104	0.236	0.168

*Kainite.

the percentage of potash in the fertilizer had little effect on the soda content and on its removal in the table beet crop, but produced a decrease in percentage and removal of soda in the turnips, cabbage, and onions. With a salt application (plots 2 and 3), increase in the potash applied resulted in a decrease in the percentage and removal of soda in the first three crops but a slight increase in onions. Increase in the potash applied increased the percentage and removal of potash in the beet, turnip, and cabbage crops but gave rather inconsistent results in the onions.

Table 6 presents the soda and potash contents of kohlrabi, kale, and rape produced on the salt series of plots. Yields were not taken of the crops in the year of their analysis. When salt was applied, all three crops showed a marked increase in soda and no appreciable decrease in potash content. Application of either salt or potash, in the absence of the other resulted in a large increase in intake of the applied constituent. The death of all the kohlrabi plants on plot 12 marked it as the only one of all the crops grown on these plots to suffer to this extent.

In order to secure some information regarding possible fluctuation in soda and potash contents of the crops during growth, three of the crops were sampled at two different stages of growth in 1938. Dates of sampling of the sugar beets were September 22 and October 18, table beets August 15 and October 4, and asparagus June 14 and September 19. The first asparagus harvested was in the cooking stage, while the second was the fully grown crop. The analyses of the samples are presented in Table 7.

The sugar beet roots generally showed a slight decrease and the tops a greater decrease in soda content toward maturity when salt was applied with potash. Without salt, the low soda content usually became slightly increased at maturity. When salt was applied, the potash content of the beet roots decreased slightly. On the water-free basis, the tops showed considerable decrease in potash at maturity no matter what treatment, but this marked decrease appeared only with the heaviest applications of potash (plot 4) and of salt (plot 5) when the calculation was made on the green basis.

When potash was applied, all salt treatments produced a considerable increase in soda content of table beet roots as the crop reached maturity. The same was true of the tops when no salt was applied; but, with salt, the soda content at maturity was lower when calculated on the dry basis and remained fairly uniform on the green basis. With all treatments the potash content of both tops and roots increased from the immature to the mature stage.

With all treatments the soda content of the asparagus was low but increased considerably as the crop matured. When potash was applied, the potash content was lower at maturity on all plots when calculated on the water-free basis but was higher on the green basis. The potash content of the asparagus was very much higher than the soda content and was not appreciably affected by the salt application.

SODIUM VS. CHLORIDE

In order to determine whether or not the benefit from the salt was due to the sodium or the chloride, sodium sulfate was included in

TABLE 8.—*Effects of varying proportions of sodium sulfate in the fertilizer application to muck soil upon the yield and composition of 1937 crops.**

Plot Nos.	Annual sodium sulfate application, 1934–37†	Yield, tons per acre	Total moisture, %	Percentage in crop, average of plots indicated: Water-free basis				Percentage in crop: In green crop				Pounds per acre removed by crop			
				Na_2O	K_2O	Cl	SO_4	Na_2O	K_2O	Cl	SO_4	Na_2O	K_2O	Cl	SO_4
Table Beet Roots															
1, 11, 15	500	8.90	90.86	2.64	5.60	2.52	0.697	0.240	0.508	0.231	0.064	42.83	90.03	41.43	11.36
3, 10, 14	0	7.52	90.73	0.75	7.65	2.56	0.699	0.069	0.706	0.237	0.065	10.88	112.26	37.06	10.22
Sugar Beet Tops															
1, 11, 15	500	6.10	74.61	1.14	3.35	1.13	0.659	0.292	0.847	0.287	0.167	35.46	104.03	35.10	20.43
3, 10, 14	0	4.27	72.95	0.30	3.47	1.12	0.587	0.080	0.942	0.302	0.159	6.87	81.15	25.85	13.59
Sugar Beet Roots															
1, 11, 15	500	7.50	79.18	0.33	1.44	0.120	0.251	0.068	0.299	0.025	0.052	10.19	44.70	3.79	7.83
3, 10, 14	0	6.52	78.67	0.06	1.55	0.092	0.200	0.014	0.330	0.019	0.043	1.76	43.06	2.55	5.58

*Fertilized annually, 1934–37, 800 lbs. per acre of 0–8–24 (C. P.) fertilizing materials.

†The 500-pound-per-acre application of sodium sulfate ($Na_2SO_4.10H_2O$) contained only 36.4% as much soda as did the 500-pound salt (NaCl) application reported in preceding tables.

treatments on another set of plots on the same field. The land was more shallow muck and somewhat drier than the original salt series. The results given in Table 8 show that benefits were secured with sodium sulfate similar to those produced with ordinary salt, indicating that it is the sodium which is responsible for the benefits produced. Determination of chloride and of sulfate showed the composition to be fairly uniform whether or not sodium sulfate was applied. Considerably more of each was removed in the sugar beet roots when sodium sulfate was applied than when it was omitted.

In Table 9 are presented the soda and chloride contents of the 1937 crops of sugar beets and celery produced on the salt series and the amounts removed per acre. Although the percentages of soda in the sugar beet and celery crops were generally quadrupled when salt was applied, the chloride content was increased only to about one-half more than when no salt was used. Doubling the potash application (plot 4) decreased the chloride content of the sugar beet roots but

TABLE 9.—*Effects of varying salt and potash applications to muck soil on the chloride content of plants.*

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre	Salt applied annually, 1932–37, lbs. per acre	Crop yield, tons per acre, 1937	Total moisture, %	Na_2O %	Chlorides		
						Water-free basis %	In green crop %	Pounds per acre removed by crop
				SUGAR BEETS				
				Tops				
1, 6, 11	0–8–24	0	4.84	71.84	0.59	1.33	0.375	36.30
2	0–8–12	500	5.71	72.25	2.04	2.01	0.558	63.72
3, 8, 10	0–8–24	500	5.51	74.32	1.78	2.14	0.550	60.61
4	0–8–48	0	5.00	72.48	0.54	1.78	0.490	49.00
5	0–8–24	1,000	4.50	76.61	2.05	2.22	0.519	46.71
7, 9	0–8–24*	0	5.83	75.60	1.17	1.73	0.422	49.25
12	0–8–0	500	5.50	66.60	2.62	1.29	0.431	47.41
				Roots				
1, 6, 11	0–8–24	0	5.12	80.75	0.25	0.25	0.047	4.81
2	0–8–12	500	7.99	80.84	0.67	0.23	0.043	6.87
3, 8, 10	0–8–24	500	7.88	79.08	0.58	0.29	0.060	9.46
4	0–8–48	0	7.51	78.78	0.08	0.13	0.028	4.21
5	0–8–24	1,000	7.68	77.21	0.41	0.24	0.054	8.29
7, 9	0–8–24*	0	7.47	77.73	0.45	0.17	0.038	5.68
12	0–8–0	500	3.19	85.47	2.90	0.85	0.123	7.85
				CELERY				
1, 6, 11	0–8–24	0	18.19	91.13	0.89	3.40	0.303	110.23
2	0–8–12	500	21.40	91.36	4.01	4.05	0.350	149.80
3, 8, 10	0–8–24	500	26.12	92.27	3.52	4.80	0.371	193.81
4	0–8–48	0	22.16	90.16	1.37	4.31	0.424	187.92
5	0–8–24	1,000	25.57	93.40	3.93	5.65	0.373	190.75
7, 9	0–8–24*	0	28.11	92.28	3.09	4.85	0.374	210.26
12	0–8–0	500	9.36	90.11	5.78	3.23	0.319	59.72

*Kainite.

increased that of the beet tops and celery. Use of salt without potash (plot 12) increased the chloride content of the beet roots greatly and of the tops slightly but had little effect on that of the celery crop. The conclusion that sodium is the beneficial element is further supported by the fact that all plots, except plot 12 of the salt series, annually had also received chloride in the form of the muriate of potash used in the fertilizer mixture, yet an outstanding benefit had been secured from the salt applications.

EFFECT UPON COMPOSITION OF SOIL

Owing to the fact that the continued use of salt on heavy mineral soils tends to injure the tilth of the soil, attention was given the physical condition of the salt series plots, some of which had received heavy annual salt applications for 8 years. Insofar as could be determined, the salt has produced no unfavorable physical effects on the muck soil. To determine any chemical changes resulting from the soil treatments which might affect the continued response of crops to salt, samples from soil layers 1 to 10 inches, inclusive, and 13 to 24 inches, inclusive, were analyzed. The results appear in Table 10. The sections were so taken as to have the upper one entirely within the plowed layer and the lower one entirely below. The samples were purposely taken April 4, 1938, just preceding the 1938 salt applications so that a year had elapsed since the last applications.

The analyses show no consistent correlations with treatment in the content of the various soil constituents, except for a decided increase in soda and chloride and a slight decrease in potash where salt was applied. Although the chemical composition of the crops from these plots indicates that, on the average, the greater the application of salt, the greater the amount of potash which was removed by most crops, the increase in potash removed is not sufficient to account for the decrease in the residual potash left in the soil of the salt plots. It would appear that the application of salt has slightly increased the leaching out of the potash.

It is evident that both soda and potash are held in the soil to a much greater extent than is the chloride with which they were combined. This is further supported by the fact that the content of chloride was higher in the 13- to 24-inch layer than in the 1- to 10-inch layer, while both soda and potash were considerable greater in amount in the upper layer. Nitrogen, lime, phosphate, iron oxide, and magnesia showed no correlation with the fertilizer treatments, but the iron oxide showed a natural, gradual increase and the magnesia a decrease from plots 1 to 12.

DISCUSSION

This study concerning the effects of salt applied as a fertilizing material on crops grown on a Michigan muck soil has showed that 12 crops have produced paying increases when the salt was applied along with potash. Not all crops have thus far been included in this study, so that it is probable that other crops will, from time to time, be added to the list. Attention should be called to the fact that this experiment was conducted under practical field conditions with ordin-

TABLE 10 *Effect of six annual applications of salt upon the composition of muck soil.**

Plot No.	Fertilized annually, 1932–37, 600 lbs. per acre	Salt applied annually, 1932–37, lbs. per acre	Percentage calculated to water-free basis											
			Organic matter	Total ash	Soluble ash	Insoluble ash	N	P_2O_5	Cl	K_2O	Na_2O	Fe_2O_3	CaO	MgO
Samples From 1–10 Inches														
1, 6, 11	0–8–24	0	84.74	15.26	10.63	4.63	2.67	0.188	0.033	0.130	0.024	0.610	4.87	0.541
2	0–8–12	500	85.31	14.69	10.25	4.44	2.50	0.169	0.055	0.115	0.124	0.508	4.75	0.517
3, 8, 10	0–8–24	500	85.21	14.79	10.24	4.55	2.59	0.187	0.053	0.118	0.092	0.633	4.74	0.506
4	0–8–48	0	85.12	14.88	10.48	4.40	2.50	0.171	0.038	0.134	0.034	0.506	4.92	0.503
5	0–8–24	1,000	85.27	14.73	10.02	4.71	2.49	0.178	0.065	0.083	0.216	0.566	4.67	0.538
7, 9	0–8–24†	0	85.02	14.98	10.39	4.59	2.69	0.201	0.036	0.112	0.058	0.700	4.79	0.469
12	0–8–0	500	85.01	14.99	10.60	4.39	2.62	0.213	0.036	0.071	0.069	0.786	4.89	0.471
Samples From 13–24 Inches														
1, 6, 11	0–8–24	0	89.58	10.42	8.42	2.00	2.50	0.098	0.033	0.080	0.020	—	—	—
2	0–8–12	500	88.86	11.14	8.83	2.31	2.39	0.095	0.056	0.044	0.045	—	—	—
3, 8, 10	0–8–24	500	89.53	10.47	8.61	1.86	2.54	0.098	0.060	0.065	0.050	—	—	—
4	0–8–48	0	90.41	9.59	7.94	1.65	2.68	0.101	0.043	0.088	0.022	—	—	—
5	0–8–24	1,000	90.41	9.61	7.94	1.67	2.68	0.104	0.105	0.070	0.116	—	—	—
7, 9	0–8–24†	0	89.96	10.04	8.31	1.73	2.62	0.104	0.047	0.071	0.037	—	—	—
12	0–8–0	500	90.08	9.93	8.30	1.63	2.68	0.104	0.057	0.057	0.050	—	—	—

*The aqua regia digestion method of the Bremen (Germany) Peat Experiment Station was used in these analyses.
†Kainite.

ary commercial superphosphate and muriate of potash used in making up the fertilizer mixtures. It is probable that some of the crops which showed no increases from the salt application would have shown slight responses if fertilizing materials containing no sodium as an impurity had been used.

The crops which showed a response to salt may be placed in two groups with regard to the degree of that response. The first group which is comprised of those crops which showed marked benefit from salt includes celery, mangel wurtzels, Swiss chard, sugar beets, table beets, and turnips. The second group includes those crops which showed a slight but generally paying response to salt, namely, cabbage, celeriac, kale, kohlrabi, radishes, and rape. As a result of this study, an application of salt is being recommended for the muck soils of Michigan at the rate of 500 to 1,000 pounds per acre for the first-named group of crops and at the rate of 100 to 400 pounds for the second group. A considerable amount of salt is now being used on the celery and sugar beet fields on Michigan muck land.

This response of the crop to salt has been confined to three plant families, namely, the beet (*Beta*), the mustard (*Cruciferae*), and the parsley (*Umbelliferae*) groups. Of the crops studied, all of the four members of the beet family showed marked response to salt. In the mustard family, six members, cabbage, kale, kohlrabi, radishes, rape, and turnips responded, while three, broccoli, Brussels sprouts, and rutabagas, did not. In the parsley group, two members, celery and celeriac, were benefited, while three, carrots, parsley, and parsnips, were not. It would appear, then, that the salt requirement of these 12 crops is a characteristic which may have been acquired in the later evolution of the plants.

Among the 10 other crops reported above which have not shown any appreciable response to salt, eight other families are represented. It should be noted that one of these, asparagus, although in years past considered to be a salt-responsive crop, has showed no benefit from salt in five years of tests on these muck plots.

Past investigations (9) regarding the effect of the application of a sodium salt on the absorption of potash have been somewhat inconsistent, but, in general, the conclusion has been drawn that the removal of potash by the crop is somewhat reduced in the presence of a sodium salt. The explanation offered assumes the replacement of the potassium ion with sodium in the metabolic processes of the plant. In the present study the percentage of potash in the plant has not been reduced to any considerable extent by the salt application, except in the case of sugar beets. When salt was applied, celery, table beets, onions, and kohlrabi showed slight decreases in potash content, turnips and kale slight increases, and cabbage, rape, and asparagus no appreciable change. Of the six crops on which yield data were secured, sugar beets and onions were the only ones to show any decrease in amount of potash removed by the crop when salt was applied, while table beets showed little change and cabbage, celery, and turnips considerable increases in removal of potash.

The results have been very consistent in showing that the several crops benefited by sodium have given higher yields with a half appli-

cation of potash plus salt than with a full application without salt. Thus, the 0–8–12 plus salt and the 0–8–24 plus salt have generally outyielded, respectively, the 0–8–24 and the 0–8–48 mixtures without salt. In some instances the effect on yields of the 0–8–12 mixture plus salt has compared favorably with that of the 0–8–48 without salt.

In order to bring out a clearer picture of the effect of the application of each material on the assimilation of the other, Table 11 was prepared, showing the percentage assimilation by the crops of both the soda and the potash applied to the plots receiving them. It is evident that when the percentage of potash in the analysis applied is reduced from 24 to 12, the percentage of soda absorbed is considerably increased. With the potash entirely omitted (plot 12), the absorption of soda was much reduced in all crops except sugar beets which showed a marked increase. In general, then, the presence of a fair supply of potash is necessary if the greatest absorption of salt is to be secured.

In Table 11, B, the percentage of applied potash absorbed by the crops shows an inverse ratio to the amount applied. On the average, the application of salt has not appreciably affected the proportion of applied potash which was absorbed. Although these data tend to confirm the theory that soda may substitute to some extent for a lack of potash in the metabolic processes of the plant, they also indicate that, in the presence of ample potash, the application of a sodium salt is not likely to reduce the absorption of potash.

The fact that salt applied without potash has failed to give satisfactory yields of any crop and has resulted in unhealthy growth of all crops, with strong evidence of potash deficiency and also a marked decrease in purity and content of sugar beets, is definite evidence that soda cannot perform all of the functions of potash in the metabolism of the plant. The very marked increases in yield of the salt-responsive crops, from salt applied along with potash, over the yields secured with either potash or salt alone indicates that there must be a definite function which soda plays in the metabolic processes of certain plants.

There is strong evidence in the data presented that soda is decidedly dependent on the presence of potash in whatever growth function it is active. This fact was not recognized by Comin (1, page 493) who, as a result of a 5-year study of the effects of salt applied to celery on otherwise unfertilized muck soil, concluded that, "there seems to be no merit in using commercial salt to increase celery yields". This very definite interrelationship between plant food elements is not an abnormal one, since phosphate, when applied without potash to most Michigan muck soils, likewise produces yields of practically all crops (2) somewhat lower than are secured without any fertilizer whatever, yet, when applied along with potash, it produces much higher yields than does potash alone.

In order to present the variation which exists in the potash-soda ratios of the several crops analyzed, Table 12 was prepared, showing the ratios for six of the plots and the averages for the 10 crops analyzed. The data present a striking correlation between the ratios and the crop response to salt. The first four crops in the table are certain

TABLE 11.—*Percentage assimilation of soda and of potash applied as salt and muriate of potash, respectively, to muck soil.**

Plot No.	Potash in fertilizer mixture, %	Salt, lbs. per acre	Turnips, 1938	Table beets, 1938	Cabbage, 1939	Celery			Sugar beets			Av. of 5 crops
						1937	1938	Av.	1937	1938	Av.	
A, % Assimilation of Na_2O												
2	12	500	29	66	18	60	71	66	28	62	45	45
3, 8, 10	24	500	19	48	11	56	64	60	18	51	34	34
5	24	1,000	6	29	10	25	34	29	7	15	11	15
12	0	500	16	46	10	35	46	40	47	66	56	34
B, % Assimilation of K_2O												
1, 6, 11	24	0	41	70	77	91	57	74	49	71	60	64
2	12	500	66	99	94	120	63	91	64	88	76	85
3, 8, 10	24	500	47	59	84	102	48	75	43	60	51	63
4	48	0	38	51	60	87	51	69	37	40	30	51
5	24	1,000	66	68	90	80	69	75	50	48	49	70

*In calculating these percentages, the average amount assimilated on the plots which did not receive an application was assumed to represent what the crop could secure from the untreated soil and was subtracted from the total amount absorbed by the crop before calculating the percentage of the application assimilated.

to give a marked increase in yield from a salt application, rape and cabbage are likely to respond to salt but to a less degree, kohlrabi and kale will show a benefit unless they have been heavily fertilized with commercial potash, while onions and asparagus will not show a benefit from salt. This leads to the conclusion that the narrower the potash-soda ratio, the greater the increase in yield which may be expected from a salt application applied along with potash.

TABLE 12.—*Ratio of potash to soda in crops grown on muck soil fertilized as indicated.*

Crop and portion analyzed	Fertilizer used and pounds per acre of salt applied						Av. of plots receiving potash
	0-8-48; no salt	0-8-24; no salt	0-8-24; 500 lbs. salt	0-8-24; 1,000 lbs. salt	0-8-12; 500 lbs. salt	0-8-0; 500 lbs. salt	
Table beets:							
Tops	4.4	3.2	1.0	1.0	0.78	0.22	
Roots	4.3	3.2	0.8	0.8	0.56	0.19	
Total	4.3	3.2	0.9	0.9	0.64	0.20	1.98
Celery:							
Above-ground part	4.7	3.6	0.8	0.8	0.49	0.14	2.05
Sugar beets:							
Tops and crowns	4.7	4.6	0.8	1.1	0.72	0.15	
Roots (crowned)	16.4	7.9	2.2	3.2	1.46	0.16	
Total	5.4	5.2	1.0	1.3	0.85	0.16	2.77
Turnips:							
Tops	8.4	2.6	1.2	2.2	0.77	0.17	
Roots	8.9	2.6	1.6	2.4	0.96	0.32	
Total	8.5	2.6	1.3	2.3	0.83	0.19	3.09
Rape:							
Above-ground part	8.4	6.2	1.9	2.6	2.16	0.23	4.25
Cabbage:							
Heads	17.1	10.2	4.0	2.8	2.07	0.38	
Stumps	14.3	6.3	3.3	2.4	1.07	0.25	
Above-ground part	16.9	9.6	3.9	2.8	1.92	0.34	7.02
Kohlrabi:							
Leaves	16.0	6.8	2.7	2.3	1.88	—*	
Balls	38.8	16.8	8.1	5.4	4.23	—*	
Above-ground part	28.6	14.4	5.4	4.3	3.23	—*	11.19
Kale:							
Above-ground part	34.1	12.5	3.6	4.2	1.83	0.24	11.25
Onions:							
Bulbs	49.5	33.5	11.9	7.3	14.58	1.08	23.23
Asparagus:							
Above-ground part	59.3	28.1	13.5	13.0	9.40	1.62	24.65

*Crop died.

The data and field observations secured in this study, both regarding crop yields and soil composition, show that as a result of repeated applications of salt there is a gradual accumulation of soda in the soil

to the extent that a heavy rate of application made annually should be reduced somewhat in later years. In this regard, however, attention should be called to the fact that in most rotations of muck crops salt-responsive crops are not likely to be grown very many years in succession. It also seems fair to conclude from all information secured in this study that a heavy application of salt applied for such crops as celery, table beets, or turnips will provide sufficient residual soda in the muck soil the following year for the production of such less-responsive crops as cabbage, kohlrabi, and rape. It is important to note that even though a fairly heavy application of salt has been made for a series of years, there is not likely to be sufficient residual salt in muck soil the following year to have any toxic effect on a non-responsive crop.

There has been some indication in these studies that the relative response of the salt-responsive crops is correlated with the seasonal climate. In some years it has appeared that the occasionally greater response of certain crops to the 500-pound-per-acre salt application over that secured by 1,000 pounds may have resulted from a checking of growth during a droughty period in those summers, since the crops on the plot receiving the heavier application have almost always looked better in the early stages of growth than those receiving the lighter salt application. There is also evidence that in periods of heavy rainfall there has been a slightly greater leaching of potash from the plots receiving the heavy salt application to the extent that the crops suffered from potash hunger. Thus, in the 8-day period from August 25 to September 1, 1940, a total of 7.03 inches of rain (10) fell on the plots at East Lansing, with the result that the salt-responsive crops on plot 5 developed some indications of potash deficiency later on, while a check-up showed practically no water-soluble potash in the soil of any of the plots.

In the early days of celery farming in the Kalamazoo district, the land was fertilized by heavy applications of manure shipped in from Chicago. After many years of celery raising, some growers found that they secured a benefit from salt applied in addition to the manure. On other farms the salt failed to produce any appreciable benefit, possibly because of insufficient potash in the soil to balance the soda and permit its utilization. With the advent of motor vehicles and the corresponding shortage of manure, the celery farmers were rapidly forced to change to commercial fertilizer. About this time, the benefits from salt appeared to cease, apparently due either to the build-up of soda in the soil from the applications of previous years or to the greater amounts of salt present as an impurity in the lower grades of potash used at that time. On some of these old celery fields, salt is again being used with satisfactory benefits.

From the analyses made of sugar beets, table beets, and asparagus at an immature and a mature stage, it appears that crops may not contain a maximum of soda at maturity, but that the rate of accumulation may vary with different crops and may even reach the maximum somewhat before maturity. Since yields were not secured at the time of the first sampling, there is no indication in the data presented that the total amount of soda held by the immature crop was

as much as that held by the crop at the time of harvest. The fact that sugar beets show a marked response to salt in early growth suggests an early absorption of soda. It is unfortunate that this study of seasonal trend did not include several dates of sampling, not only of the crops studied but also of celery and turnips which ordinarily do not show physical effects of the salt application until late in growth.

SUMMARY

From a study of the effects of ordinary salt applied along with varying mixtures of phosphate and potash on Michigan muck soil, the following conclusions may be drawn:

1. Application of salt as a fertilizing material along with a phosphate-potash mixture showed the following effects:

   A. Increases in yield of the following crops:

   (a) Four members of the beet (*Beta*) family, *viz.*, mangel, sugar beet, Swiss chard, and table beet
   (b) Two members of the parsley (*Umbelliferae*) family, *viz.*, celery and celeriac
   (c) Six members of the mustard (*Cruceriferae*) family, *viz.*, cabbage, kale, kohlrabi, radish, rape, and turnip

   B. Decreases in contents of N, CaO, and MgO and slight increases of P_2O_5 in crops of celery and sugar beets

   C. Very marked increases in Na_2O and Cl contents of those crops which showed yield increases

   D. Little or no decrease in the percentage of K_2O in the salt-responsive crops

   E. Slight decrease with sugar beets, no appreciable change with table beets, and marked increases with cabbage, celery, and turnips, in the total amount of K_2O removed in the crop

   F. No appreciable effect on sugar content and purity of beets, but an improvement in health of several crops and in eating qualities of celery

   G. Considerable increase in Na_2O content and slight decrease in K_2O content of soil

2. Application of salt in the absence of potash fertilization gave the following effects:

   A. Very low yields of all crops grown
   B. Unhealthy growth of roots; in a decayed condition at harvest
   C. Chlorosis of foliage growth indicative of potash deficiency
   D. Markedly decreased sugar content and percentage purity of beets

3. As a result of this study, recommendations for the use of salt as a fertilizing material on muck soil can be made as follows:

   A. The application of salt should always be accompanied by an application of potash in amount sufficient to satisfy crop needs

B. Yield increases are likely to justify the use of salt at the following rates:

(a) Initial application of 500 to 1,000 pounds per acre for celery, mangels, sugar beets, Swiss chard, table beets, and turnips, with 500 pounds per acre in succeeding years for these salt-responsive crops

(b) 100 to 400 pounds-per-acre applications for cabbage, celeriac, kale, kohlrabi, radishes, and rape

(c) No salt application for asparagus, barley, broccoli, Brussels sprouts, carrots, corn, lettuce, oats, onions, parsley, parsnips, peppermint, potatoes, spinach, and tomatoes

4. The relation of potassium and sodium in the metabolism of the salt-responsive crops may be summarized as follows:

A. The sodium ion appears nearly as much needed as a nutrient for these crops as is the potassium ion

B. The so-called "luxury consumption" of potash by a crop which shows yield increases from salt may be due at least partially to a soda-starvation of the crop

C. In the absence of sufficient potash for proper plant nutrition a crop which shows yield increases from salt may develop a "luxury consumption" of soda

D. The probability of a crop response to salt can be anticipated by the composition of the crop produced under ordinary fertilization, as follows:

(a) A low natural soda content indicates that there will be no response to salt, while a high soda content indicates a probable marked response to salt

(b) A narrow potash-soda ratio in a crop indicates a salt-responsive crop, a wide ratio a non-responsive crop

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NONSYMBIOTIC NITROGEN FIXATION IN SOILS OF A SEMI-ARID REGION OF NORTH CHINA[1]

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IT has occasionally been suggested that fixation of nitrogen by nonsymbiotic microorganisms is more active in soils of a semi-arid region than elsewhere. While engaged in agricultural work in a semi-arid part of North China, the author observed that the conditions favoring an activity of nitrogen-fixing organisms, often pointed to in regions with such a climate, also exist there. The soils are calcareous, well aerated, and low in total nitrogen (0.08 to 0.09%), and crop residues are of types having a wide carbon-nitrogen ratio.

At the same time, although not heavily fertilized, yields of field crops are better than might be expected with so low a content of total nitrogen, winter wheat on irrigated land commonly yielding between 30 and 35 bushels per acre and reaching 60 bushels. The appearance of the growing crop also is good. This is particularly true of fields of winter wheat which, with few exceptions, are of deep green color throughout the growing period. It seemed possible, therefore, that an active nonsymbiotic fixation of nitrogen might be an important factor in the apparent fertility of these soils.

The study reported in this paper was carried out in an attempt to determine the extent to which this is the case. All work was done on a single soil type, on one of the larger plains of Shansi Province in the vicinity of Taiku. This soil is a deep, well-drained silt loam derived from material of alluvial and aeolian origin. The laboratory experiments, including all analyses, were made in the laboratories of the New York State College of Agriculture at Ithaca.

The investigation, in total, included three principal groups of experiments. Their description, and a statement of the results obtained, follow.

FIELD EXPERIMENTS WITH NITROGEN FERTILIZATION

The purpose of this group of experiments was to determine to what extent the common nonleguminous crops would respond when treated with applications of a nitrogenous fertilizer. Considering the low level of the nitrogen content of these soils, if a large response is obtained there can be seen more reason to suspect that nitrogen is being supplied through some action within the soil itself.

These studies were conducted in the field. Over a period of 4 years, 17 different experiments were carried out with four different crops

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on 13 fields. All were replicated and laid out in ways which made possible a statistical analysis of the results. The fields, about one-half of which were rented from farmers, were for the most part of average fertility and representative of the ordinary tilled soils of the area. They were in part irrigated and in part unirrigated. In the majority of cases the treatments were with ammonium sulfate, with Chilean nitrate of soda being used in the remaining experiments. These materials were applied in furrows from 2 to 3 inches deep at the side of the crop rows, with rates varying from 240 to 320 pounds per acre. The crops used were winter wheat, millet, buckwheat, and kaoliang.

Results obtained from these experiments are presented in Table 1. Data show that in only 1 of the 17 experiments was the grain yield of the nitrogen-treated plots more than 31.4% above that of untreated plots. The exceptional case occurred in a field recognized to be among the poorest in the neighborhood. In a majority of the 12 experiments using summer crops, increases were between 20 and 30%. In the five experiments with winter wheat, the largest increase amounted to 12.5%. Increases of straw yields closely paralleled those of grain,

TABLE 1.—*Field responses to applications of nitrogenous fertilizers.*

Exp. No.	Yield of grain, bu. per acre		Gain or loss compared with check			Yield of straw, lbs. per acre		Gain or loss compared with check	
	Check	Nitrogen treated	Bu. per/ acre	%	Significance	Check	Nitrogen treated	Lbs. per/ acre	%
					Winter Wheat				
1	32.4	34.6	2.2	6.8	33:1*	2,995	2,953	-43	-1.4
2	37.3	36.4	-0.9	-2.4	<5%‡	2,759	2,789	30	1.1
3	33.5	37.7	4.2	12.5	1999:1*	2,478	2,792	314	12.7
4	23.0	23.6	0.6	0.3	2:1*	3,657	4,120	463	12.7
5	23.0	22.5	-0.5	-0.2	2:1*	3,657	3,597	-60	-1.7
					Millet				
6	51.1	61.5	10.4	20.4	285:1*	3,606	4,236	630	17.5
7	72.5	87.9	15.4	21.2	384:1†	7,773	9,462	1,689	21.7
8	21.7	37.2	15.5	71.4	>1%‡	3,523	5,134	1,611	45.7
9	35.0	46.0	11.0	31.4	>1%‡	5,081	5,760	679	13.4
10	38.8	41.9	3.1	8.0	<5%‡	6,201	6,268	67	1.1
11	14.6	17.6	3.0	20.5	525:1*	831	1,015	184	22.1
12	14.2	17.0	2.8	19.6	>1110:1*	801	1,004	203	25.3
					Kaoliang				
13	24.0	28.9	4.9	20.4	212:1*	4,069	4,615	547	13.4
					Buckwheat				
14	35.2	36.3	1.1	3.1	16:1*	2,582	3,104	522	20.2
15	32.6	32.5	-0.1	-0.1	1:1*	2,362	2,775	413	17.5
16	26.0	30.4	4.4	16.9	18:1*	3,005	6,713	3,708	123.4
17	24.6	31.5	6.9	-8.0	212:1*	3,110	5,686	2,576	82.8

*Odds from Student's "t" for paired data.
†Odds from Student's "t" for unpaired data.
‡By analysis of variance.

except in two experiments with buckwheat. High figures were obtained in these cases, due in part to yields that were actually greater, but in part also to an incomplete drying of the more succulent growth of the nitrogen-treated plots.

In certain of these experiments the fertilization record of the fields in previous years was not obtained, but experiment No. 3 was known to have been conducted on a field which had not been fertilized during at least the two seasons previous to its use for this experiment. Experiments Nos. 6 and 13 were conducted on successive years on another field known not to have received any nitrogenous fertilizers during the four years previous to the first of these experiments. Evidence from other experiments indicated that moisture in these cases was adequate for the fertilizing materials to have taken effect, particularly for experiments Nos. 3 and 13.

These results, therefore, suggest that the crops growing on untreated plots were able to draw substantially upon some source of nitrogen within the soil itself. While these experiments do not demonstrate what that source is, they leave open the possibility that nonsymbiotic fixation may have provided a significant amount. It is to be noted that, whatever the source, the amount available appears to be more abundant in soils planted to winter wheat than in those to which summer crops are planted.

NONSYMBIOTIC FIXATION UNDER FIELD CONDITIONS

EXPERIMENTS WITH ARTIFICIAL PLOTS

Two experiments were conducted under approximately field conditions in an attempt to determine, by measurement, whether or not nonsymbiotic fixation actually contributes significant amounts of nitrogen to these soils. The first of these experiments was designed primarily to find out to what extent the nitrogen level of soils in the field is lowered by the demands of growing crops. It was reasoned that if the content of total nitrogen showed little change over a period of years of cropping this would constitute evidence suggesting that fixation by nonsymbiotic organisms had supplied an important part of the nitrogen required by the growing crop.

To obtain this information, use was made of small artificial plots similar in type to the frames used at the Cornell University Experiment Station at Ithaca, N. Y. These frames were 4 by 8 feet in size and were surrounded by a wall constructed of bricks laid in mortar. The area so enclosed was first excavated to a depth of 1 foot, after which it was refilled in two layers, 0 to 6 inches and 6 to 12 inches, with material taken from corresponding depths of a cultivated field. Six such plots were prepared and treated identically.

The experimental period extended over six growing seasons from the spring of 1934 to the fall of 1939. During this period, common field crops were grown each year without addition of a nitrogenous fertilizer. Precautions were also taken to prevent the admixture of wind-blown material during the dry months of winter and early spring. Stalks and grain were removed at harvest time, only roots and stubble being returned to the soil. The soil of each plot was care-

fully sampled at the beginning and end of the experimental period and analyses were made to determine its content of total nitrogen.

These and other nitrogen determinations in this study were made with the Kjeldahl method, as recommended by the Association of Official Agricultural Chemists (4).[3]

The data of this experiment are shown in Table 2. In the surface 6 inches of soil, an average loss of 152 pounds of nitrogen per 2,000,000 pounds of soil was recorded. The average loss in the lower 6 inches was 38 pounds, making a total loss of 190 pounds. Analysed with Student's "t" method, this loss was found to be highly significant in the upper layer and significant in the lower.

TABLE 2.—*Change in total nitrogen content of soils of artificial plots after six seasons of cropping at Ithaca, N. Y.*

Frame No.	Percentage N			
	0–6 inch layer		6–12 inch layer	
	1934*	1939†	1934*	1939†
I	0.0853	0.0797	0.0593	0.0571
II	0.0846	0.0770	0.0593	0.0559
III	0.0851	0.0765	0.0578	0.0588
IV	0.0876	0.0777	0.0591	0.0575
V	0.0846	0.0790	0.0601	0.0567
VI	0.0862	0.0782	0.0575	0.0557
Total	0.5134	0.4681	0.3531	0.3417
Average	0.0856	0.0780	0.0589	0.0570
Diff. %	−0.0076		−0.0019	
Diff. Lbs. per/acre‡	− 152		− 38	
Odds by Student's "t"	1110:1		52:1	

*Beginning of experiment, average of duplicate determinations.
†End of experiment, average of duplicate determinations.
‡Based on 2,000,000 pounds per acre.

Although it was not originally intended that a determination should be made of the amount of nitrogen removed in the harvested crops, it later seemed desirable to attempt an estimation of this figure for comparison with that found to have gone from the soil. The amount of nitrogen removed in this manner may perhaps be considered to constitute the only important source of removal which can be determined, since it is not likely that appreciable losses in drainage occurred under existing rainfall conditions.

The harvested weights of materials were used as a basis to make this estimation. The percentage of nitrogen contained in the crops was obtained in part by an analysis of similar material and in part by estimate, using average figures quoted by Morrison (3). In order to

[3]Figures in parenthesis refer to "Literature Cited", p. 992.

allow for moisture still remaining in the air-dry stalks and straw, the harvested weights of these were uniformly reduced by 12%.

The result of the calculations made on this basis is shown in Table 3. Because estimated, the figures have to be accepted only as giving an approximate measure of the amounts of nitrogen removed by crops during the experimental period. This removal on an average of the six plots is at the rate of 205 pounds per acre. This figure, it is seen, corresponds closely with the 190 pounds found to have been lost by the upper foot of soil during the same period.

No evidence is found in this experiment, therefore, to suggest that important amounts of nitrogen are being added to this soil by non-symbiotic fixation. For the nitrogen needed in growth, the crops appear rather to have drawn from the meager stores of this element existing in the soil at the beginning of the experimental period.

EXPERIMENTS WITH LARGE POTS

In the second experiment of this group soils were cropped for a period of time under approximately field conditions and evidence regarding the fixation of nitrogen was looked for in the nitrogen balance remaining after known additions and removals had been accounted for. In determining this balance, careful determinations were made of the following: The content of total nitrogen in the soil at the beginning and end of the experiment, the amounts of nitrogen added to the soil in seed and applied organic materials, and the amounts of nitrogen removed in the crops harvested. The nitrogen added in rainfall was not determined. The experimental period extended through two seasons, from the spring of 1938 to the fall of 1939.

In conducting this experiment there were used large nonporous pots of glazed earthenware sunk into the ground to within a few inches of their tops. By this plan it was sought to approximate field conditions while, at the same time, so limiting the quantity of soil that error due to sampling would be reduced to a minimum. The pots were of local manufacture, having inside diameters of about 16 inches at the top and 11½ inches at the bottom, an inside depth of about 15½ inches, and a capacity of about 11 gallons. The soil was taken from the upper 6 inches of a cultivated field of average fertility and was added to each pot in definite weight after careful mixing and sampling.

In order to widen somewhat the range of conditions studied, three series of pots were set up with six replicates in each series. The amounts and forms of material applied in each of these series were as follows:

Series	1938	1939
I	None .	Stalks and residues of 1938 crop
II	Millet rootlets at rate of 2.5 tons per acre; wheat straw at rate of 2.5 tons per acre	Stalks and residues of 1938 crop; millet leaves at rate of 2 tons per acre
III	Millet rootlets at rate of 5 tons per acre; wheat straw at rate of 5 tons per acre	Stalks and residues of 1938 crop; millet leaves at rate of 4 tons per acre

TABLE 3.—*Crop yields and estimate of nitrogen removed from artificial plots by crops.**

Year and crop		Plot No. 1		Plot No. 2		Plot No. 3		Plot No. 4		Plot No. 5		Plot No. 6	
		Yield per acre, lbs.	N, lbs.	Yield per acre, lbs.	N, lbs.	Yield per acre, lbs.	N, lbs.	Yield per acre, lbs.	N, lbs.	Yield per acre, lbs.	N, lbs.	Yield per acre, lbs.	N, lbs.
1934, millet:	Grain	2,310	44.8	2,409	46.7	2,349	45.6	2,438	47.3	2,495	48.4	2,287	44.3
	Straw	2,468	15.1	2,623	16.0	2,252	13.7	2,396	14.6	2,803	17.1	2,695	16.4
1935, kaoliang:	Grain	1,513	25.4	1,627	27.3	1,826	30.7	1,499	25.2	1,546	26.0	1,461	24.5
	Straw	2,218	11.3	2,081	10.6	2,356	12.0	2,403	12.3	2,246	11.5	2,134	10.9
1936, buckwheat:	Grain	464	8.3	864	15.5	566	10.1	629	11.3	363	6.5	461	8.3
	Straw	501	4.2	933	7.7	611	5.1	679	5.6	392	3.3	489	4.1
1937, millet:	Grain	198	3.8	315	6.1	179	3.5	85	1.6	120	2.3	50	1.0
	Straw	190	1.5	302	1.8	172	1.0	82	0.5	115	0.7	48	0.3
1938, buckwheat:	Grain	1,052	18.8	932	16.7	961	17.2	767	13.7	719	12.9	568	10.2
	Straw	791	6.6	886	7.4	971	8.1	920	7.6	835	6.9	720	6.0
1939, maize:	Grain	2,895	44.9	2,387	37.0	2,042	31.7	1,869	29.0	1,987	30.8	1,869	29.0
	Straw	4,342	40.8	3,580	33.7	3,063	28.8	2,804	26.4	2,981	28.0	2,804	26.4
Total:	Grain	—	146.0	—	149.3	—	138.8	—	128.1	—	126.9	—	117.3
	Straw	—	79.5	—	77.2	—	68.7	—	67.0	—	67.5	—	64.1
Grand total..................		—	225.5	—	226.5	—	20.75	—	195.1	—	194.4	—	181.4

*Average amount of N in crops (average of 6 plots), 205 pounds per acre.

The pots were cropped with buckwheat in 1938 and with a short-season millet in 1939. During the entire spring and summer period, moisture was kept at near optimum by additions of distilled water when rainfall was insufficient. To prevent the addition of wind-blown material, all pots were covered with muslin cloth during the winter and early spring.

Analytical data from these studies are given in Table 4. Considering first the data from series 1, it is seen that, like results in the artificial plots, the content of total nitrogen in the soil was significantly reduced. It is seen further, however, that when additions and removals of nitrogen in plant material are accounted for, the balance still shows a loss. This unaccounted for loss amounts to an average of 36.2 pounds per acre for a 2-year period, a figure of a size which could hardly be accepted as significant had it come from the analytical data of a single pot. Analysis with Student's "t" method, however, shows that this average difference is highly significant; and it seems demonstrated, therefore, that a real unaccounted for loss has occurred.

In the data from series II, the nitrogen balance also shows an average unaccounted for loss, but the amount is less than that of series I and not significant when analysed statistically. For series III, no loss but a slight, though quite insignificant, gain was recorded. Thus, the addition of increasing amounts of organic matter seems to have progressively reduced the amount of unaccounted for loss appearing in the nitrogen balance. In no case do the data present evidence that important amounts of nitrogen have been added by fixation.

LABORATORY TESTS OF NONSYMBIOTIC FIXATION

Additional experiments were conducted in the laboratory to obtain information regarding the inherent fixing power of this soil as compared with that of other soils. The soils used in this comparison were: "Shansi 1938", the soil used in the experiment with large pots; "Shansi 1939", the same soil after treatment with organic matter as of series III; Honeoye silt loam, obtained from the Soil Conservation Farm at Marcellus, N. Y.; and Dunkirk silty clay loam, taken from a limed portion of Caldwell Field of the Cornell Station. The following are their total nitrogen contents and pH values:

Soil	Total N, %	pH
Shansi 1938	0.085	8.04
Shansi 1939	0.086	7.98
Honeoye silt loam	0.246	7.42
Dunkirk silty clay loam	0.141	6.01

PLAQUE TESTS

It has been suggested that the number of macroscopic colonies of Azotobacter appearing on soil plaques may be used as an indication of the fixing power of a soil. To make a comparison of the soils in this study with this method, three series of plaques were prepared, with treatments as follows: (a) Sugar only, 2% of weight of soil; (b) sugar,

2% plus KH_2PO_4, applied in a 2% solution; and (c) sugar, 2% plus magnesium ammonium phosphate 2%. In addition, precipitated calcium carbonate at the rate of 0.2% was added to Honeoye and Dunkirk soils, being omitted from the Shansi soils because preliminary trials had shown it to be without value.

Plaques were prepared in the usual manner in triplicate, except in the case of the magnesium ammonium phosphate treatment. For these plaques the soil was diluted with sterile sand in the ration of 1 to 3, and six plaques of each soil so diluted were prepared. Plaques were placed in an incubator at 260° to 280° C for a period of about 30 hours after which counts were made with a microscope.

All the soils included in this comparison produced colonies with each of the treatments used. While the number of colonies varied with the treatments, the ranking of the soils, as determined by the number of colonies that appeared, was the same in each case. The largest number of colonies was present on the Honeoye soil, the second largest on the Dunkirk, and the least on the Shansi soil.

FIXATION IN TUMBLERS

A comparison of the amounts of nitrogen fixed by activity in these soils, when placed under defined conditions, was made with 100-gram samples of soil in tumblers, induplicate, incubated at a temperature of 260° to 280° C for 30 days. KH_2PO_4 was added at the rate of 0.05% of the weight of the soil. Calcium carbonate at the rate of 0.1% was added to the Dunkirk and Honeoye soils at the beginning of the experiment, and at the same rate to all soils after 20 days. Moisture was adjusted with frequent applications of distilled water to one-half the maximum water-holding capacity of each soil.

As energy material, sugar in solution was added at the rate of 1% at the beginning of the experiment and subsequently at the same rate at the end of each 10-day interval. This procedure was designed to keep the carbohydrate material continuously available in all soils.

The data from this experiment show that there were large differences in the amounts of nitrogen fixed by the different soils, as is seen in Table 5. This amount in the case of the Shansi soil was approximately four times as great as that fixed by the Honeoye soil. No gain at all was shown by the Dunkirk soil.

FIXATION IN SOLUTION CULTURES

As a check on these results, a second test was made using solution cultures. These were prepared by adding 10 cc of a soil suspension to a nutrient solution. This suspension was made by mixing thoroughly with an electric milk shaker 50 grams of soil in 150 cc of distilled water. The nutrient solution was made up following a modification of Winogradski's method as used by Curie (1). Fifty cc of this solution were placed in 500-cc Kjeldahl flasks in which the cultures were incubated. As energy material, 1.2 grams of sugar were added per flask, making the solution approximately 2% with respect to this material.

Treatments were in quadruplicate. Two of these were at once sterilized to be used as checks, and the remaining two were incubated

TABLE 4.—*Nitrogen balance in pot experiments receiving nitrogen from different sources.*

Pot No.	N additions					N removals				Gain or loss of N, grams
	Soil N at beginning		N in seed, grams	N in organic matter, grams	Total N, added, grams	Soil N at end		N in crops harvested, grams	Total N removed, grams	
	%*	Grams per pot				%*	Grams per pot			
Series I, Plant Residues Only										
3	0.0815	38.817	0.038	—	38.855	0.0786	37.436	1.141	38.577	−0.278
5	0.0802	38.198	0.038	—	38.236	0.0773	36.816	0.907	37.723	−0.513
7	0.0820	39.055	0.038	—	39.093	0.0785	37.388	0.871	38.259	−0.834
12	0.0812	38.674	0.038	—	38.712	0.0787	37.483	0.677	38.160	−0.552
13	0.0807	38.436	0.038	—	38.474	0.0773	36.816	0.845	37.661	−0.813
17	0.0806	38.388	0.038	—	38.426	0.0785	37.388	0.864	38.252	−0.174
Total, grams										−3.164
Av. per pot, grams										−0.527
Lbs. per acre										−36.2
Odds†										416:1

Series II, Organic Matter, 7 Tons Per Acre										
2	0.0809	38.531	0.038	0.875	39.444	0.0818	38.960	0.766	39.726	+0.282
6	0.0810	38.579	0.038	0.875	39.492	0.0818	38.960	0.452	39.412	−0.080
8	0.0825	39.293	0.038	0.875	40.206	0.0819	39.007	0.606	39.613	−0.593
10	0.0806	38.388	0.038	0.875	39.301	0.0812	38.674	0.744	39.418	+0.117
15	0.0814	38.769	0.038	0.875	39.682	0.0814	38.769	0.845	39.614	−0.068
18	0.0814	38.769	0.038	0.875	39.682	0.0810	38.579	0.506	39.085	−0.597
Total, grams										−0.939
Av. per pot, grams										−0.157
Lbs. per acre										−10.8
Odds†										7:1
Series III, Organic Matter, 14 Tons Per Acre										
1	0.0809	38.531	0.038	1.750	40.319	0.0836	39.817	0.813	40.630	+0.311
4	0.0817	38.912	0.038	1.750	40.700	0.0863	41.103	0.346	41.449	+0.749
9	0.0814	38.769	0.038	1.750	40.557	0.0832	39.627	0.367	39.994	−0.563
11	0.0814	38.769	0.038	1.750	40.557	0.0847	40.341	0.417	40.758	+0.201
14	0.0829	39.484	0.038	1.750	41.272	0.0843	40.150	0.810	40.960	−0.312
16	0.0818	38.960	0.038	1.750	40.748	0.0836	39.817	0.756	40.573	−0.175
Total, grams										+0.211
Av. per pot, grams										+0.035
Lbs. per acre										2.4
Odds†										1:1

*Average of duplicate determinations.
†Student's "t" method.

at between 26° and 28° C. The length of the incubation period was determined by the length of time, as judged by appearances, taken by the most active of these soils just to use up completely the added sugar. Since energy material would remain available in all flasks only up to this point, it was expected that stopping the action at that time would give results showing the relative rates of fixation under approximately comparable conditions.

TABLE 5.—*Nitrogen fixation in tumblers after 30 days, with sugar applied at 10-day intervals.*

N content of duplicate tumblers, %*	N content of check, %	Gain or loss of N compared with check, mgms
	Shansi 1939	
0.1038	0.0864	17.4
0.1068	0.0864	20.4
Av.		18.9
	Honeoye	
0.2498	0.2455	4.3
0.2497	0.2455	4.2
Av.		4.3
	Dunkirk	
0.1407	0.1412	-0.5
0.1391	0.1412	-2.1
Av.		-1.3

*Average of two determinations.

Action proceeded most rapidly in flasks containing the Shansi soils which appeared to have used up completely the added carbohydrate material at the end of one week. Analytical data showing the amount of nitrogen gained by fixation during this period are given in Table 6. According to these data, the Shansi cultures fixed approximately 70% more nitrogen than was fixed by the Honeoye cultures, and a bare beginning in fixation was made in the Dunkirk cultures.

These results, therefore, although differing in degree, are similar in kind to those obtained in the tumbler experiment. Over a period of time during which energy material was constantly available in all soils, a greater amount of nitrogen was fixed by activity in the Shansi soils than in the others. No correlation is observed, however, between the rate of fixation as found in these experiments and the number of colonies that appeared on soil plaques. While no explanation is attempted, it is of interest to note that a similar lack of agreement was found by Turk (5).

DISCUSSION

The field studies of this investigation appear to show that, in the absence of applied fertilizers, substantial quantities of nitrogen were available to growing plants out of supplies in the soil. No evidence

has been found, however, to show that this supply originated from the activity of free-living, nitrogen-fixing microorganisms. Instead, the source seems to have been in that supply which already existed in the soil when the experiments were begun.

TABLE 6.—*Nitrogen fixation in solution cultures.*

Percentage N fixed					
Shansi 1939		Honeoye		Dunkirk	
Duplicates	Average	Duplicates	Average	Duplicates	Average
Incubated Samples					
0.0118 0.0127	0.0123	0.0132 0.0126	0.0130	0.0056 0.0063	0.0060
Unincubated Samples					
0.0027 0.0025	0.0026	0.0078 0.0065	0.0072	0.0036 0.0046	0.0041
Average Gain, Mgms N					
	9.7		5.8		1.9

Caution should be exercised, however, in drawing from these results the broad conclusion that the amount of nitrogen fixed in soils of this region is under no condition of much practical importance.

The amount of nonsymbiotic fixation in a soil appears to be greatly affected by conditions, and there exist in Shansi several important conditions which were not included in any of the experiments thus far completed. One of these is in soils where wheat is grown as indicated by the particularly low response to nitrogen fertilization shown by that crop in this study. A second is the situation in soils receiving applications of manure. Numerous investigations (2, 6, 7) have shown that when a moderate amount of manure is present in the soil an increased amount of fixation follows, and manuring in moderate amounts is a common local practice in the region in question.

In addition, it is to be noted that, as indicated from the laboratory tests, this soil appears to possess a relatively high inherent fixing power.

Conditions may exist, therefore, under which fixation is more active and of greater practical importance than under those which have been studied. It might be concluded that, although this possibility is not excluded, the results of these studies seem strongly to indicate that, with summer crops, grown on soils receiving no fertilizer additions, or additions only of a highly carbonaceous organic matter, the amount of nitrogen added by nonsymbiotic fixation is not sufficient to constitute an appreciable part of that used by the growing crop.

SUMMARY

Studies have been conducted in a semi-arid part of North China having conditions generally considered to be very favorable for an active nonsymbiotic nitrogen fixation to determine to what extent nitrogen is added to soils in this region by this process.

The response of field crops to applications of nitrogenous fertilizers was tested in 17 field experiments. The yield of intertilled summer crops was increased by fertilization in a majority of cases by 20 to 30%. Increases of the grain yield of winter wheat did not exceed 12.5% in any of the five experiments in which this crop was grown.

The changes in total nitrogen content of a soil over a period of years of cropping was determined in an experiment using small artificial plots cropped for six successive seasons without the addition of nitrogeneous materials. Results showed that the soil underwent a definite loss of nitrogen and that the amount so lost was approximately the same as that removed in the crops harvested.

In a second experiment designed to measure the amount of nitrogen added to the soil by fixation, soil was placed in large pots sunk in the ground, and a nitrogen balance was drawn up after treatment and cropping for 2 years. In one of the three series of this experiment a definite unaccounted for loss of nitrogen occurred. In no case was a positive gain by fixation shown.

In laboratory tests it was found that a greater number of macroscopic colonies of Azotobacter appeared on soil plaques of Honeoye silt loam and Dunkirk silty clay loam than on those made with China soils; but nitrogen was found to be fixed at an appreciably more rapid rate by the last-mentioned soil than by the other two in tests with soil in tumblers and in solution cultures.

It is doubted whether conclusions can be drawn from this work which will apply to all the common conditions of cropping and management of this soil. It seems to be indicated, however, that the summer crops grown on soils not receiving fertilizer additions, or with additions only of high carbonaceous organic matter, the amount of nitrogen added by nonsymbiotic fixation is not sufficient to constitute an appreciable part of that required by the growing crop.

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BULK EMASCULATION AND POLLINATION OF SMOOTH BROMEGRASS, *BROMUS INERMIS*[1]

WAYNE E. DOMINGO[2]

THE minuteness of the floral parts of some species of forage grasses which have perfect flowers renders hybridization by hand difficult and tedious. A more efficient technic of emasculation and pollination is necessary if populations adequate for field tests are to be obtained. The study herein reported was designed to determine the feasibility of using different methods of bulk emasculation and bulk pollination on forage grasses such as smooth bromegrass (*Bromus inermis*).

ISOLATION EQUIPMENT

Isolation was effected in all cases by means of 3 by 26 inch kraft bags. Each bag was supported by a 4-foot No. 9 wire, one end of which was thrust into the ground at the base of the plant and the other end enclosed in the bag that it supported. A horizontal loop, 1.75 inches in diameter, in the upper end of the wire prevented the sides of the bag from collapsing against the inflorescences.

Observations of the flowering processes of isolated panicles were facilitated by 1.75 inch square holes cut near the sealed ends of the bags and covered with a transparent plastic, Plastacele.[3] A good seal between the kraft and the Plastacele was obtained by soaking 0.25 inch of the border of a 2.75 inch square of Plastacele in acetone until a layer of partially dissolved plastic was formed (45 to 60 seconds), immediately placing the square over the 1.75 inch hole in the kraft bag, and pressing the edges of the plastic firmly to force the partially dissolved plastic into the pores of the kraft. The bag was ready for use as soon as the highly volatile acetone had evaporated.

EMASCULATION

REVIEW OF LITERATURE

Bulk emasculation has been attempted on at least four species of the Gramineae family by the utilization of temperatures to which the staminate organs of the perfect flowers are more susceptible than are the pistillate organs.

Stephens and Quinby (9)[4] investigated the possibility of emasculating sorghum plants by subjecting the inflorescences to hot water. Although their results were

[1]Contribution from the Utah Agricultural Experiment Station, Logan, Utah, and the U. S. Dept. of Agriculture, Bureau of Plant Industry, Division of Forage Crops and Diseases. Part of a thesis submitted to the graduate school of the Utah State Agricultural College in partial fulfillment of the degree of master of science. Received for publication June 26, 1941.

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[3]Plastacele of 0.005 inch thickness was purchased from du Pont de NeMours and Co., Arlington, N. J.

[4]Numbers in parentheses refer to "Literature Cited", p. 1002.

not altogether consistent, the evidence obtained indicated that such emasulation was possible and deserved further investigation.

Jodon (4) emasculated rice by hot water treatments at 40° to 44° C and by cold water treatments at 0 to 6° C for 10 minutes.

Li, *et al.* (5) observed no differential in the thermal death points of the staminate and pistillate organs of millet (*Setaria italica*). Few hybrid seeds were produced on heads which were isolated with normal flowering heads as a pollen source after being treated with hot water over a range of temperatures some of which permitted normal selfed seed to be produced, while others destroyed both the male and female organs. Since little hybrid seed was produced by this normally cross-pollinated species, even on heads which received the less severe treatments and which produced many selfed seeds, it seems possible that lack of hybrid seeds might have been due not to lack of differential in the thermal death points of the two types of organs, but to some other factors, such as failure of normal opening of the glumes.

Suneson observed widespread sterility in wheat exposed to frosts at the bloom stage. In later experiments (10) he obtained partial emasculation of wheat by subjecting plants to temperatures varying between 27° and 36° F for 15 to 24 hours 1 to 5 weeks before heads emerged from the boot.

EXPERIMENTAL METHODS AND RESULTS

Plants which had previously exhibited the capacity to produce considerable selfed seed when isolated in kraft bags were selected for treatment. Hot water, hot air, and cold air treatments were tried in the summer of 1939, and the hot water studies were continued on greenhouse plants in the winter of 1939–40 and on field plants in 1940. All of the 1939 treatments were made at seven different stages of maturity, beginning when the panicles were emerging from the boot and continuing at 4-day intervals thereafter until just prior to anthesis.

The success of emasculation was measured in all cases by dividing the four or more panicles simultaneously receiving a given treatment into two groups, isolating one group in a bag and exposing the other to wind-borne pollen from adjacent plants, and comparing the seed sets on the two groups of panicles. Treatments which effected complete emasculation without appreciable injury to the female organs were detected by lack of seed formation on the isolated panicles accompanied by formation of seed on the panicles which received the same treatments but remained exposed to atmospheric pollen. The lack of seed set on isolated panicles indicated that as far as the formation of selfed seed was concerned the panicles were emasculated, and the formation of seed on the corresponding exposed panicles indicated that the female organs were still functional.

Hot water treatments.—The 1939 hot water treatments were made for 5 minutes at 1° intervals from 37° to 51° C at each of the seven stages of maturity by immersing the panicles in water contained in a 1-gallon thermos jug. The percentages of seed set (number of seeds produced divided by the total number of florets) obtained on the panicles which were either isolated or exposed following the treatments from 43° to 50° C at the last three stages of maturity are shown in Table 1.

TABLE 1.—*Percentage seed set on groups of two panicles of smooth bromegrass which were either isolated or exposed to atmospheric pollen after being treated with hot water for 5 minutes.**

Temperature, °C	Days after boot stage					
	16		20		24	
	Panicles exposed	Panicles bagged	Panicles exposed	Panicles bagged	Panicles exposed	Panicles bagged
50°	0	0	0	0	0	0
49°	0	0	13	0	0	0
48°	0	0	12	0	0	0
47°	54	0	24	0	—	—
46°	43	0	71	2	29	0
45°	59	0	93	11	39	1
44°	—	12	91	8	41	3
43°	78	18	88	8	48	2
None	81	24	88	31	65	—

*Average number of florets 207.

Results from the first four stages of maturity are not presented because the plants were accidently exposed to drought conditions. Seven of the treatments made at the last three stages of maturity prevented seed set on the isolated panicles yet permitted an average of 67 seeds per panicle to be produced on similarly treated panicles exposed to atmospheric pollen. Those treatments were 45°, 46°, and 47° C 16 days after the boot stage; 47°, 48°, and 49° C 20 days after the boot stage; and 46° C 24 days after the boot stage or just prior to normal anthesis. Since a plant of different genotype was treated at each of the seven stages, it is possible that different genotypes have somewhat different critical temperatures.

Hot water treatments on the greenhouse clones were made for 5 minutes at temperatures between 44° and 49° C 1 or 2 days prior to normal flowering. In the absence of abundant atmospheric pollen some panicles receiving each treatment were pollinated by artificial methods. At only the 46° treatment was seed production prevented on unpollinated panicles and permitted on the pollinated panicles. The number of seeds produced in the greenhouse was low; even the untreated panicles produced little selfed seed as compared to that produced on the same genotype in the field.

All treatments in the summer of 1940 were made at 47° C for 5 minutes 1 or 2 days prior to normal flowering. These data, presented in Table 2, were classified on the basis that those emasculation treatments were successful which permitted production of less than 1 seed per isolated panicle but at least 20 seeds per panicle exposed to atmospheric pollen. These arbitrary standards were established with the opinion that less than 1 selfed seed per panicle is not seriously objectionable and that 20 or more hybrid seeds per panicle would make the method distinctly preferable to hand emasculation. Obviously, treatment generally was too severe. The arbitrary standard

TABLE 2.—*Number of seeds per panicle produced on 17 genotypes of smooth bromegrass which were selfed but not treated or treated with water at 47°C for 5 minutes and selfed or exposed.*

Genotype No.	Seeds per panicle		
	Not treated selfed*	Treated	
		Selfed†	Exposed‡
Satisfactory Emasculation			
3, plant a	16.8	0.3	33.7
3, plant b	2.8	0.2	20.0
8	39.3	0.3	30.3
10	12.0	0.0	29.0
13	4.5	0.4	43.6
17	98.0	0.0	93.5
Unsatisfactory Emasculation			
1	6.9	0.0	0.0
2	110.6	1.2	2.3
3, plant c	18.3	0.0	6.4
3, plant d	5.7	0.4	0.2
4	22.3	0.0	3.8
5	32.1	3.8	10.2
6	26.1	0.0	0.0
7, plant a	8.0	0.0	7.2
7, plant b	4.8	0.7	0.3
9	2.1	0.0	12.0
11	6.2	0.0	8.6
12	13.4	0.0	18.0
14, plant a	52.5	0.0	0.8
14, plant b	38.9	6.3	5.8
15	1.3	0.0	1.4
16	2.3	0.4	0.3

*Average number of panicles 8.5.
†Average number of panicles 5.0.
‡Average number of panicles 4.7.

of 20 seeds is a low limit and represents only about 10% of a normal seed set.

Hot air treatments.—Hot air treatments were also tested over a range of 37° to 51°C at each of the seven stages of maturity. The hot air apparatus was designed to permit treatment of panicles without bending the stems and to eliminate the dead-air space which makes accurate temperature control very difficult. It consisted of a collapsible, rubber-walled air-chamber within a metal chamber containing the temperature-controlling water. The entire apparatus was lowered over the upright panicles of a plant, after which the rubber-walled chamber was permitted to collapse from the weight of the water. This forced most of the air from the chamber and placed the panicles in close contact with the heat source.

Of these treatments, 18 prevented the formation of selfed seed yet permitted the formation of an average of 51 seeds on the corresponding exposed panicles. The results, however, were more erratic than those obtained by the hot water treatments.

Cold air treatments.—Panicles were treated with cold air at near 0°C for periods of 4, 10, and 20 minutes at each of the seven stages of maturity. The apparatus described above was used and a mixture of ice, salt, and water in the outer portion maintained the temperature desired. None of the cold air treatments used injured the floral organs appreciably as evidenced by the absence of appreciable decrease in the amount of seed produced on treated, selfed panicles as compared with that produced on panicles that were merely selfed. Successful treatments would require temperatures sufficiently low to inactivate the pollen.

POLLINATION

REVIEW OF LITERATURE

Bulk pollen transfers have been made on several species of the Gramineae family by several different methods. Webber (11) described the use of kraft bags to collect corn pollen and transfer it to the silks of the female parents. Jelinek (2) and Rosenquist (8), working with wheat, and Reed (7), working with sorghum, obtained hybrids by isolating heads of the male and female parents in the same isolation bag. Coulter (1) applied corn pollen to the silks by means of an atomizer. Corn hybrids have been produced by Jenkins (3) and wheat hybrids by Rosenquist (8) by placing the severed, pollen-bearing portion of the male parent in a vial of water inside the bag which isolated the female organs. Pope (6) and Reed (7), working with barley and sorghum, respectively, obtained hybrids by shaking the pollen-shedding heads of the staminate parent over heads of the pistillate parent.

EXPERIMENTAL METHODS AND RESULTS

Plants which had previously exhibited little capacity to produce selfed seed when isolated under kraft bags were selected as female parents. Bulk pollen transfers from male to untreated female parents were attempted by six methods, one in the summer of 1938 and five in the summer of 1939.

A genetic basis for the identification of smooth bromegrass hybrids was not known. However, a satisfactory method of determining the efficiencies of the various pollination methods was employed. At least five panicles on each of the relatively self-sterile female parent plants were selfed. Other isolated panicles on the same plants received pollen from the male parent plants by several transfer methods. All pollinations were made when many stigmas were extruded. Success of pollen transfers was measured by determining the number of seeds produced on the pollinated panicles in excess of the number produced on the selfed panicles of the same plant. The excess was assumed to be hybrid seed resulting from the pollen transfer.

Bag transfer.—Nearly 800 stems on 30 plants were pollinated in the summer of 1938 by allowing the pollen of the male parents to dehisce into isolation bags and transferring the bags to the previously isolated panicles of the female parents. Some of the pollinations were made at various intervals of time following anthesis, which usually occurred in late afternoon, and others were repeated on consecutive days during the week of greatest anthesis but at various times during the day. These data are presented in Table 3. Over 400 selfed panicles on the

30 female parent plants indicated a degree of self-fertility sufficient to produce an average of only 2.4 seeds per panicle under kraft bags.

Panicles pollinated immediately after pollen had been shed produced an increase of 29.2 seeds per panicle over the selfed seed set. When pollen transfers were delayed until 5:30 to 8:00 a.m. on the morning following anthesis, the panicles produced an increase of 13 seeds per panicle over the selfed seed set. Pollinations made between 8:00 a.m. and noon on the day following anthesis resulted in an average increase of 5.6 seeds per panicle. Pollinations made between 1:00 and 5:00 p.m. on the day following anthesis, but prior to any pollen-shedding on that day, resulted in an average increase of 1.6 seeds per panicle which is not significant at the 5% level. These data indicate that the pollen of smooth bromegrass loses its viability within 24 hours after being shed under conditions existent in kraft bags and therefore stress the necessity of making such pollinations immediately after anthesis.

Two series of pollinations by the bag transfer method were repeated on consecutive days during the week of greatest anthesis but at various times during the day. Sixty-nine panicles were pollinated on each of 3 consecutive days, and 74 panicles were pollinated on each of 5 consecutive days. Panicles pollinated on 3 consecutive days produced an increase of 9.4 seeds per panicle, while those pollinated on 5 consecutive days produced an increase of 14.9 seeds per panicle. All of the pollinations were made between 8:00 a.m. and noon on days following anthesis with the exception of one day on which a pollination of both the 3-day and the 5-day series was made. On that day the 3-day series was pollinated in late afternoon after a small amount of pollen had been shed. The 5-day series was pollinated later in the afternoon when more pollen had been shed.

Panicles of male and female parents isolated together.—Clones of two relatively self-sterile plants were growing sufficiently close together to permit panicles from each to be enclosed in the same bag. Ten such pairings were made several days prior to anthesis with four panicles of each plant isolated in each bag. Each group of four panicles was considered a pollen source for the other four panicles in the same bag. The stems of one parent plant were consistently taller than those of the other parent, resulting in the panicles of these stems being in a higher position. The panicles in the lower position produced an increase of 62 seeds per panicle over the selfed seed set on panicles of the same plant, while the panicles in the higher position produced only 5.6 hybrid seeds per panicle (Table 4, method a).

Severed panicles of the male parent placed in the isolation bag of the female parent.—Eight isolation bags on the female parent contained four panicles each. Shortly after pollen had been shed on a day of general anthesis, groups of four panicles were severed from the male parent and placed in the top of each bag covering panicles of the female parent with the resultant average increase of 7.7 seeds per panicle over the selfed seed-set (Table 4, method b).

Air current over severed panicles of the male parent.—Fourteen bags each isolated four panicles of the female parent, and an equal number of bags each isolated four panicles of the male parent. Shortly after pollen

TABLE 3.—*Seed production on panicles of relatively self-sterile plants of smooth bromegrass following bag transfer of pollen at four intervals subsequent to anthesis and for various numbers of times during the week of greatest anthesis but at various times during the day compared with seed production on the same plants by selfing.*

Pollinations made	Number of plants used as female parents	Number of bags transferred	Total number of panicles pollinated	Av. number of seeds per panicle		
				On pollinated panicles	On selfed panicles	Gain due to transfer
In late afternoon immediately following anthesis	18	51	200	32.2	3.0	29.2†
From 5:30 to 8:00 a.m. on the morning following anthesis	12	38	147	16.5	3.5	13.0†
From 8:00 a.m. to noon on the morning following anthesis	11	29	111	9.1	3.4	5.6*
From 1:00 to 5:00 p.m. on the afternoon of the day following anthesis but prior to anthesis on the same day	19	49	186	3.4	1.8	1.6
Once on each of 3 consecutive days during the week of greatest anthesis but at various times during the day (see text)	15	18	67	13.0	3.6	9.4†
Once on each of 5 consecutive days during the week of greatest anthesis but at various times during the day (see text)	11	20	74	18.4	3.5	14.9†

*Significant at the 5% level.
†Significant at the 1% level.

had been shed on a day of general anthesis, each group of four stems of the male parent was cut below its isolation bag, and the bag containing the panicles was carried to the bag which isolated the panicles of the female parent. A small hole was cut in a top corner of each bag and the two holes placed together. A current of air was blown from the worker's mouth through the bag which isolated the panicles of the male parent into the bag which isolated the panicles of the female parent. Sufficient viable pollen was transferred by this method to produce 7.6 hybrid seeds per panicle (Table 4, method c).

TABLE 4.—*Number of seeds produced on panicles of relatively self-sterile plants of smooth bromegrass following pollination with foreign pollen by five different methods compared with the number produced on selfed panicles of the same plants.*

Method of pollen transfer	Identity of female parent	No. of pollinated panicles	Av. number of seeds per panicle		
			Pollinated panicles	Selfed panicles	Gain due to transfer
(a) Isolating panicles together:					
Lower	16–4	40	62.1	0.1	62.0†
Upper	16–5	39	5.8	0.2	5.6*
(b) Placing severed panicles of male parent in the bag isolating the panicles of the female parent	8–30	32	8.0	0.3	7.7*
(c) Passing air current over severed panicles	8–30	55	7.9	0.3	7.6†
(d) Atomizer	16–2	84	3.9	0.0	3.9
(e) Passing air current over intact panicles of male parent	20–4	79	3.8	0.2	3.6†

*Significant at the 5% level.
†Significant at the 1% level.

Atomizer.—A mass of pollen from the male parent was collected during anthesis and blown onto 84 panicles of the female parent by means of an atomizer, with a resultant increase of 3.9 seeds per panicle over the selfed seed set. This increase is not significant at the 5% level (Table 4, method d).

Air current over intact panicles of the male parent.—An air current passed into the bag which isolated panicles of the male parent and out through 8 feet of 0.3-inch rubber tubing to the bag which isolated panicles of the female parent carried sufficient viable pollen to produce an average increase of 3.6 seeds on 79 panicles (Table 4, method e).

DISCUSSION

Bulk emasculation of smooth bromegrass is possible because of the differential in the thermal death points of the staminate and pistillate

organs and the fact that functional stigmas are extruded from the glumes of florets treated at temperatures sufficiently high to destroy the viability of their pollen.

The most consistent emasculation results were obtained by hot water treatments. The less intimate contact between the florets and the heat source in the hot air method, as compared with the hot water method, may account for the results obtained thereby. Cold air treatments were not sufficiently extensive to warrant conclusions.

The obvious differences in the success of pollen transfer methods might have been altered by the use of the same parentage for all methods. However, since these data indicate that sufficient pollen can be transferred by most of the methods to produce significant increases in seed set over selfed seed set, other factors, such as proximity of parent plants and availability of labor, might govern a choice of method more than the number of seeds produced.

The lack of satisfactory seed increases by the atomizer method is attributed to the fact that smooth bromegrass pollen collected in bulk at field temperatures quickly forms large aggregates which are not easily caught by the feathery stigmas.

Emasculation data in Table 2 suggests physiological differences within a genotype as well as between genotypes which might affect the critical temperature. More careful control of such factors as time of day of treatment and soil conditions may be necessary if a common treatment is to be used for all plants.

Some of the panicles which received the 5-minute, 47° hot water treatments in 1940 were pollinated by placing severed pollen-shedding panicles in the bags isolating the panicles of the female parents. Very little hybrid seed was formed; but, since the treatments were largely too severe for successful emasculation, the lack of hybrid seed is not considered evidence against the feasibility of controlled pollination of hot water emasculated panicles. In fact, it is believed that the data presented lend support to the possibility of combining the procedures of hot water emasculation and bulk pollen transfer into a controlled hybridization program.

SUMMARY

Panicles of relatively self fertile plants of smooth bromegrass were completely emasculated by immersing them in hot water or subjecting them to hot air. More consistent results were obtained with hot water treatments. Hot water treatments between 45° and 49° C on more than 40 panicles a few days prior to normal anthesis decreased selfed seed set to less than 1 seed per panicle and permitted an average production of 52 seeds per panicle exposed to atmospheric pollen.

Bulk pollen transfers were made to unemasculated panicles by six methods. Those methods producing significant amounts of hybrid seed were (a) allowing pollen of the male parent to dehisce into an isolation bag and transferring that bag to the previously isolated panicles of the female parent shortly after anthesis, (b) enclosing living panicles of the male and female parents in the same isolation bag, (c) placing severed panicles of the male parent inside the bag

isolating the panicles of the female parent shortly after anthesis, (d) passing an air current over the severed panicles of the male parent into the bag isolating the panicles of the female parent shortly after anthesis, and (e) passing an air current over intact stems of the male parent through an 8-foot rubber tube into the bag isolating panicles of the female parent shortly after anthesis. The one method which did not produce a significant amount of hybrid seed was that of collecting the pollen from the male parent in bulk at anthesis and applying it to the panicles of the female parent by means of an atomizer.

Under conditions existent in kraft isolation bags at the time of normal anthesis in the field, pollen of smooth bromegrass lost much of its viability within 24 hours after being shed. When collected in bulk under atmospheric conditions it quickly formed large aggregates.

It seems possible that the procedures of bulk emasculation and pollination might be satisfactorily combined in a controlled hybridization program, but a more thorough investigation of the critical temperature for emasculation and of the environmental factors which affect it is a necessary preliminary.

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A SIMPLE APPARATUS FOR MEASURING NONCAPILLARY POROSITY ON AN EXTENSIVE SCALE[1]

Ross W. Leamer and Byron Shaw[2]

GROSS measurements of total pore space have failed to characterize the physical condition of soils in terms of plant response. At present the best known method of characterizing the physical condition of a soil as regards air and water relationships is the determination of pore-size distribution. Several technics have been devised for making such a determination (2, 4, 5, 6, 7).[3] Unfortunately, all these methods are too time-consuming to be used in an intensive study of soils throughout a season or over any very extensive area.

The importance of the relative amounts of large and small pores was recognized by Schumacher as early as 1864. He introduced the terms "capillary" and "noncapillary" to designate the small and large pores, respectively. These terms are obviously misnomers, but since they have received such wide recognition they will be used in this paper in their commonly accepted sense.

Dojarenko, Kvasnikov, Williams, Krause, Sekara, and other European workers have shown that the yield response of many field crops is closely associated with the distribution of the pore space within a soil. Yoder (10) found a rather consistent trend for low "capillary" pore space volume to be associated with high yield and early maturity of cotton grown in seedbeds composed of clod mixtures and of single clod separates. Nickols (8) and Randolf (9) have also demonstrated the importance of size distribution.

Bradfield and Jamison (2) stated that the "noncapillary" pores—that is those pores between the aggregates—are the ones responsible for drainage, percolation, and aeration. Nelson and Baver (7) pointed out that there is a better correlation between the pores drained at a tension of 40 cm of water and percolation and structure than at any other tension. They state that, where only one tension is to be used, 40 cm of water (pF 1.6) is the logical one in studying the physical condition of soils. Baver and Farnsworth (1) found a direct relation between the pores drained at this tension and the yield of sugar beets. These results would seem to indicate that for general work one point on the pore-size distribution curve is sufficient to give a good indication of the physical condition of the soil, if the proper point is chosen.

It is the contention of the authors that, for practical field studies, it is more desirable to use a drainage tension which more nearly approximates natural conditions. In those regions where tiling is necessary, tension (in centimeters of water) equal to the depth of tile would seem to be very satisfactory. The use of such a tension gives

[1]Contribution from the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio. Received for publication July 1, 1941.

[2]Graduate Assistant and Assistant Agronomist, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 1008.

the minimum amount of air space found in the drained soil, which is an important factor in many studies.

If percolation is the only point of interest, the tension suggested by Nelson and Baver (7) appears to be entirely satisfactory.

It is the purpose of this paper to describe a simple, inexpensive apparatus which makes possible the rapid determination of "non-capillary" pore space.

DESCRIPTION OF APPARATUS

The essential feature of any device which is to remove water from soil under tension is a continuous water column from the base of the soil sample to the surface on which the tension is being applied. The configuration of this column, or the method by which the tension is applied, is of no consequence. It is necessary to have a membrane below the soil sample which will be permeable to water and still have pores small enough that they will not be drained at the tensions applied to the water column. The higher the tension applied, the smaller the pores required.

In order to meet these requirements with as simple a set-up as possible, the apparatus shown in Fig. 1 was devised. It consists of a sheet-metal base (A) in the center of which is soldered a ¼-inch gas pipe nipple (B). Over this base is a piece of 10-mesh copper window screen (C) which is covered in turn by a double layer of ordinary smooth 200-pound weight desk blotter (D). To the nipple (B) is connected a rubber tube which runs to a leveling bottle (E).

A continuous water column is established through the rubber tube from the surface of the blotter to the surface in the leveling bottle. The pores in the blotters are sufficiently small to prevent the minisci being broken at the tensions used, but they still permit rapid water movement through the blotter. The tension is developed and controlled by regulating the pressure head between the level of the blotters and the surface of the water in the leveling bottle.

Samples to be studied are taken in an ordinary core sampling tube similar to that described by Coile (3). These cores are saturated from the bottom with water. After about 24 hours the water level in the saturation chamber is raised to as near the surface of the cylinder as possible without flooding the sample from the top. The saturated cores are then weighed, placed on the apparatus, and allowed to stand 24 to 36 hours and weighed again. The difference in weight permits the calculation of the amount of pore space in the sample drained at the tension exerted. If it is desired to determine the total pore space, the sample is then dried to constant weight in an oven at 110° C.

In order to prevent the sample from slipping out of the cylinder or to prevent any loss of the sample by slaking during saturation, a piece of cheesecloth is fastened over the bottom of the cylinder with a rubber band. This prevents any of the sample from falling out of the cylinder during weighing or transferring from the saturation chamber to the apparatus.

A little difficulty was encountered in getting the saturated weight of the more open samples because of the rapid drainage of water from

the larger pores. To overcome this difficulty a clamp was constructed which can be fastened over the bottom of the cylinder while it is still submerged. This prevents any loss of water during the transfer to

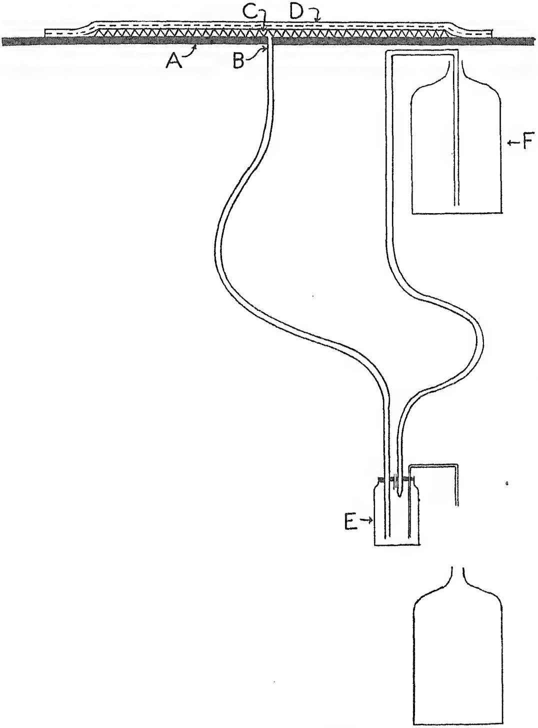

FIG. 1.—Porosity apparatus.

the scale. Knowing the volume of the cylinder, the calculation of the percentage of the volume in the larger pores is then a simple matter.

It was found that with the apparatus as described above, all samples studied came to approximately constant weight after being

in contact with the blotter for a period of 24 to 30 hours. Owing to the fiberous nature of the surface of the blotter, it is possible to remove a sample for weighing and then replace it and still have capillary contact between the blotter and the sample. This makes it possible to remove a sample at any time, weigh, replace, and reweigh until the sample has approached as near constant weight as is desired. It is necessary to keep the sample covered to prevent evaporation. A watch glass is sufficient.

There is no limit to the size to which this apparatus may be extended. An ordinary desk blotter, 19 by 24 inches, will accommodate 30 3-inch cores. If a larger area is desired, a larger blotter may be used, or the blotters may be overlapped and extended to cover the desired area. The only requirements are that there be no place where air may enter the system and that there be a continuous water column under all portions of the blotter on which samples are to be placed. The screen under the blotters serves to support them on its upper surface, thus allowing a continuous thin sheet of water to extend under the entire area. This sheet need be only thick enough to permit free lateral movement of water from the edges of the blotter to the central outlet.

For routine work it is recommended that the blotters be changed about every two weeks because there is a tendency for them to become clogged with fine material from the samples which reduces their efficiency. In the event that samples are not being run every day, the blotters will become so highly hydrated in three or four weeks that their permeability is greatly reduced. Because of the low cost, however, this does not appear to be a very serious objection, since several sets of samples may be run before the blotters become useless.

The base used may be any one of a number of materials. Galvanized sheet metal is satisfactory although it corrodes on standing in contact with the saturated blotters for a period of time. Bakelite has been found to be very satisfactory except for the initial cost. Chrome-plated ferrotype plates are also well suited for such an apparatus. An inexpensive porcelain-topped work table would seem to be an ideal support. The outlet could be soldered into the table top and the porcelain should prove very satisfactory as a surface on which to lay the blotters.

The large area of saturated surface exposed permits a large amount of evaporation. This loss from the leveling bottle may be compensated for by the use of a large flat surface of water which will supply a large amount of water without appreciably affecting the level, or by constant additions of water to replace that removed by evaporation. The latter method seems to be more satisfactory because of the greater flexibility permitted by the smaller leveling surface necessary and because of the more exact control of the level which this permits. A device found to be very satisfactory (Fig. 1) is a 250-ml wide-mouth bottle (E) which is fitted with a four-hole stopper. The water column from beneath the blotters is extended nearly to the bottom of the bottle by a glass tube through one of the holes. Another hole is fitted with a capillary siphon, the outside arm of which is shorter than the inside so that when the level drops to the level of the end of the out-

side arm no more water will be siphoned over, and the small tube forms a miniscus which prevents sucking back if the level in the bottle should drop slightly. The third hole is fitted with a glass tube drawn out to a very fine point. This capillary dropper is attached to a supply (F), in our case a 20-liter carboy sitting on the table with the apparatus, and the water drops into the leveling bottle a little faster than it is removed by evaporation and the excess is siphoned off by the capillary siphon into another carboy which may be exchanged with the one holding the supply.

OPERATION OF THE APPARATUS

Preparing the apparatus for a set of determinations consists of establishing a continuous water column from the surface of the blotters to the leveling bottle. The actual procedure recommended is to raise the end of the tube going into the leveling bottle slightly above the level of the base and to fill this tube with water until there is a little standing on the base. The screen may then be put in place and more water poured on until there is just enough to wet the screen and the base. The blotters may then be placed over this water and allowed to become saturated. It will be necessary to add more water to saturate the blotters thoroughly. Better results are obtained if they are left for a couple of hours before attempting to apply tension. To apply the tension, the water and air are squeegeed out from under the blotters with a light rolling motion (any cylindrical object will do) from the center towards the edges. As soon as the edges are smoothed down evenly all around and pressed in place the end of the rubber tube may be placed in the leveling bottle and lowered slowly to the desired position. As the leveling bottle is lowered it is best to pour more water on the surface of the blotter. This water goes through the blotter and along the screen to the center outlet and carries with it any bubbles of air that may have been trapped in the screen. As soon as all the air is removed from the system the apparatus is ready to use.

It is not necessary to use any sealing agent to hold the blotters to the base because the tension on the water column will hold them in close contact. In order to get good contact, it is necessary to have the blotters at least 1 inch wider than the screen on all edges.

New blotters are more satisfactory to use than old ones because they are more easily handled and are more permeable. After they have been saturated for two weeks or more they cannot be dried and rewet with satisfactory results. The double layer is used to give a wider range of possible tensions to the apparatus. A single blotter may have a few large pores present which will permit air to enter the system at the tension desired, but very seldom will two blotters have large pores which coincide. With the double layer it is possible to use tensions up to 100 cm of water quite satisfactorily.

Changes in temperature will affect the results obtained insofar as they affect the surface tension and the density of the water in the sample. However, for most general determinations, ordinary room temperature fluctuations are not great enough to cause any serious

error in the results. For more exact results the apparatus should be placed in a constant temperature room.

The authors believe that this apparatus will make possible a more intensive study of the physical and structural conditions of soils. An apparatus of this kind may be built from common materials and is adapted to the study of a larger number of samples than has been possible in the past.

Preliminary work suggests that this apparatus is well suited to the study of percolation rates. Indications are that it also will be useful in leaching experiments.

SUMMARY

A simple, inexpensive apparatus has been devised which makes possible the measurement of "noncapillary" porosity on a large number of samples. The apparatus uses the pressure deficiency method of removing water from a saturated sample. The pressure deficiency is developed by a difference in level of two ends of a water column. The higher end of the column is suspended by an ordinary desk blotter on which the samples are placed.

The apparatus described accommodates 30 3-inch core samples; however, there is no limit to the number that may be used.

It is suggested that this apparatus may be useful in other types of investigations.

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DISTRIBUTION OF CARBON IN MORPHOLOGICAL UNITS FROM THE B HORIZONS OF SOLONETZ-LIKE SOILS[1]

John L. Retzer and Roy W. Simonson[2]

Coatings or films which differ in appearance from the interiors of structural units have been recognized in many different soils (1, 4, 7, 8).[3] These coatings may be darker colored zones, as in the B_2 horizon of Miami silt loam (3) and on the vertical faces of the columns in Solonetz soils (5), or they may be light colored and gray as in the solodized-Solonetz soils (5, 6) and some of the Planosols in the region of the Chernozem and Prairie soils (2). The darker coatings have been variously described as organic stains, colloidal films, or simply as zones of different color.

The light-colored coatings, occasionally no more than a sprinkling of light gray or white particles on the structure faces, have been called quartz flour, "podzol dust", and silica. Both types of coatings occur on the morphological units from the B horizon of Solonetz soils, as is indicated in descriptions of those soils (5, 6). Despite the widespread occurrence and recognition of both light- and dark-colored coatings on structural units, there have been few attempts to characterize such formations quantitatively.

Data on the distribution of carbon within morphological units from the B horizons of Solonetz-like soils from California and Nevada are herewith reported.

EXPERIMENTAL MATERIALS AND PROCEDURE

Relatively large structural units from the B_2 horizons of four different soils were used in this study.[4] The four units selected for analysis are illustrated in Fig. 1, and the source location or series represented, plus a brief description of each unit, are given below.

Unit 1.—Watsonville series from Santa Cruz County, California (9). The unit was 7 inches tall and had a circumference of 11½ inches. The cross section was pentagonal, and the corners were distinct and well defined. The top of the column and a narrow band below it were faintly gray in color, whereas the faces themselves were dark brown, the intensity of the brown color decreasing toward the bottom of the unit. The interior of the column was olive-gray in color with a number of rust-brown mottlings concentrated largely in the upper part. The entire unit was rather dense, and there were few root holes or other channels visible to the eye in the soil mass.

Unit 2.—Las Flores fine sandy loam from the Escondido area, California (7). The unit, which represented a layer between depths of 20 and 27 inches, was 7 inches tall, had a circumference of 6¾ inches, and was pentagonal in cross section.

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[2]Assistant Soil Surveyor, Bureau of Plant Industry, U. S. Dept. of Agriculture, and Research Assistant Professor of Soils, Iowa State College, respectively.

[3]Figures in parenthesis refer to "Literature Cited", p. 1013.

[4]The authors are indebted to R. C. Cole for supplying unit 1 and to Ray C. Roberts for units 2, 3, and 4.

The corners of the column were sharply defined, and the cap was rounded. The column top and a band below it approximately ½ inch wide were light gray in color. The faces were dark brown, and the interior was greenish-gray with a few rust-brown mottlings. There were a few root channels and pin holes in the soil mass.

Unit 3.—Monserrate sandy loam from the Escondido area, California (7). The unit, which was 4 inches tall and had a circumference of 7¼ inches, represented a layer between depths of 14 and 18 inches. The cross section was roughly pentagonal with poorly defined corners, and the top was slightly rounded. The cap of the column and the narrow band below it were a distinct yellowish-gray color, whereas the sides were a rich dark brown. The interior also had a rich brown color with quartz grains showing as white specks on freshly broken surfaces. There were a few root channels and small pin holes present in the interior of the structural unit.

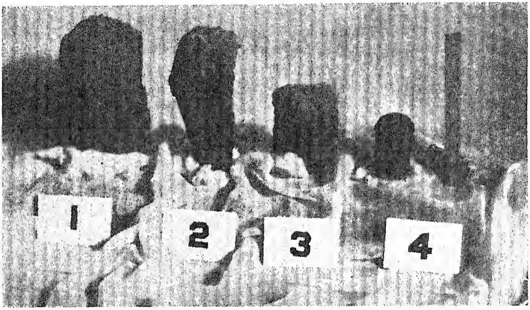

FIG. 1.—Four morphological units from Solonetz-like soils used in study of distribution of total carbon.

Unit 4.—This unit was collected near Minden, Nevada, to represent a layer between 4 and 10 inches. The unit was 3 inches tall (originally 6 inches) with a circumference of 5 inches. The cross section was roughly square, the corners were poorly defined, and the cap, though rounded slightly, was not distinct. The top of the structural unit was grayish-brown, and the sides had a rich dark brown color. The interior was light reddish brown in color and contained appreciable quantities of sand. Root holes or other channels were absent.

For the making of carbon determinations, duplicate sets of samples, each sample representing a layer 2 mm in thickness, were taken from the top and from the sides of each of the structural units. Each pair of samples, whether taken from the top or side of the column, represented one of several successive layers, each 2 mm thick, measured inward from the exterior of the unit. One pair of samples was also taken to represent the center or core of each column. The samples were all taken with a cork borer (¼ inch in diameter) fitted with a collar of rubber tubing placed 2 mm from the cutting edge. Before each sampling, the soil material was moistened to the required depth by laying a damp cheesecloth

pad over the surface of the unit or column. The cork borer was held in a position perpendicular to the surface of the column (either the top or the side) in the removal of each sampled layer. Care was exercised in each sampling to prevent the taking of a layer more than 2 mm thick, as marked by the rubber collar. The moist sample removed from the tube of the borer was air-dried, ground in a mortar, and brought to constant weight in an oven at a temperature of 110° C. The carbon content was then determined according to the procedure of Winters and Smith (10).

RESULTS AND DISCUSSION

One general trend in the distribution of carbon is evident for all of the morphological units that were studied. The highest contents of carbon are found in the outermost layer on the faces of the columns and the lowest amounts occur either in the core or in the light gray cap of the unit. The total quantity of carbon in the outermost layer on the faces or sides of the columns ranges from 0.5% in the Monserrate unit to 0.8% of the unit from the Watsonville soil. Decreases in the content of carbon from the exterior to the core of a unit range from approximately 0.13% in two of the columns to a maximum of 0.25% in one of the columns. The distribution of carbon by 2-mm layers inward from the faces of the columns is given in Fig. 2.

The quantities of carbon in the dark-colored faces of the columns range from 117 to 126% of the amounts in the second 2-mm layer and from 123 to 185% of the amounts in the cores. The higher con-

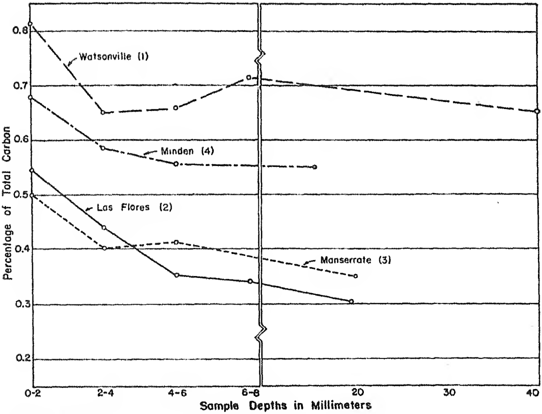

FIG. 2.—Graph showing distribution of carbon by 2-mm layers inward from the sides of the units to the centers.

centration of organic matter on the vertical surfaces of the units may be due to downward movement of partly decomposed plant residues in percolating waters, to the distribution of plant roots, or to a combination of the two influences. Plant roots are known to be more numerous in the cracks between structural units in the dense B horizons of the soils studied. The decay of such roots in place would provide greater amounts of carbon on the surfaces of the columns in the B horizons of these soils. However, some movement of organic matter is also suggested by the data for carbon distribution downward from the tops of the morphological units. These data are presented in Fig. 3.

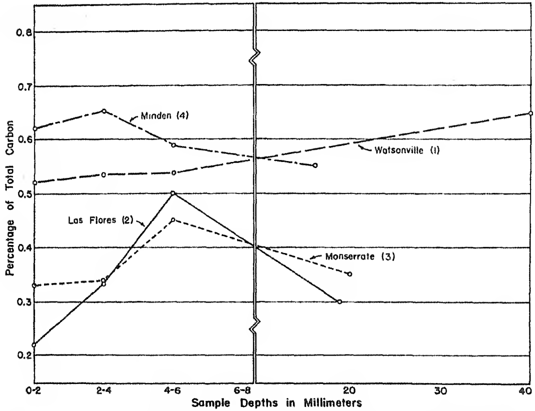

FIG. 3.—Graph showing distribution of carbon by 2-mm layers downward from the caps of the units to the cores.

The pattern of distribution of carbon from the tops of the columns to the cores is quite different from that inward from the sides. In three of the units, the lowest quantities occur in the light-colored gray cap and a maximum is found in the second or third layers. In the Watsonville unit, the content of carbon in the interior of the column is higher than that in any of the layers above it. Carbon contents of the surface layers of the column top range from 0.22% in the Las Flores unit to 0.62% in the unit from the soil at Minden, Nevada. The lowest quantity of carbon in the outer layer of the column top is associated with the most distinct light-colored and rounded cap. The light gray cap is most evident on the column from Las Flores fine sandy loam, followed in order by those from Monserrate sandy loam

from the Watsonville series and from the soil near Minden, Nevada. The concentration of carbon in the surface layer of the caps of the four columns increases in this same order.

The smaller quantities of carbon in the gray caps of the columns as compared to the amounts in the underlying 2-mm layers in the same morphological units suggests that some eluviation of organic matter has occurred. Materials other than organic matter would be expected to move at the same time, but such processes cannot be discussed adequately on the basis of observations herein reported. The movement of organic matter, either into the columns or downward between the columns, has been limited in the units studied, but some movement seems to be indicated by the changes in concentration within the structural units from the four soils.

SUMMARY

The distribution of carbon within morphological units (columns) from the B horizons of Solonetz-like soils from California and Nevada was determined. Quantities of carbon in the outermost layers on the column faces were, on the average, 123% of those in the central portions of the units, whereas the amounts in the light-colored caps were 55% of the amounts in the core or central portion. The carbon content decreased gradually from the face to the core of each unit and increased from the top of the column downward, at least for one or two mm layers. Quantities of carbon were low in all of the four columns or units studied.

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THE RELATIONSHIP OF CATALASE RATIO TO GERMINATION OF X-RAYED SEED AS AN EXAMPLE OF PRETREATMENTS[1]

B. N. SINGH[2]

THE growing interest in problems connected with the hastening of seed germination with a view to giving the necessary fillip to subsequent growth and yield of crops has resulted in recent years in the application of numerous methods to obtain reasonably prompt and complete germination of seeds. Scarification (4),[3] acid treatment (1), irradiation and delinting (5, 6, 7), chilling (3), and hormone treatment (10) are some of the measures adopted to achieve this end. Despite the considerable amount of experimental work directed to the initiation of rapid germination, however, the proximal cause of the after-effects of treatments is by no means clear.

Working on allied problems and more particularly on irradiation with X-rays using seeds of different biochemical constitution, it was observed by the writer that, whereas lighter dosages accelerate the germination process, the heavier ones definitely retard it. Since Davis (2) and, more recently, Singh, *et al.* (9) reported a direct correlation between catalase ratio and the viability of seeds, it was thought that this ratio might be used to determine the precise response of presowing treatments.

In the calculation of this ratio, the simple method of dividing the catalase activity of soaked, normal, or irradiated seed by that of normal dry seeds was utilized. The volume of oxygen liberated from H_2O_2 by a given catalase preparation was taken as an index of the degree of the enzymatic activity. The manometer adapted and described by Singh and Mathur (8) was employed for the determinations in both the dry and soaked preparations belonging to different sets. For detailed observational technic, reference may be made to a previous publication (9).

Both the catalase ratio and the germinating power of seeds of different crops investigated herein have been found to alter greatly after seed irradiation with X-rays.[4] For purposes of comparison the data obtained in each case have been presented in Table 1. These observations exhibit a close correlation between the catalase ratio and the germinating capacity of seeds. Quotients higher than normal are associated invariably with higher percentages of germination, while lower ones characterize low germination capacity. Thus, in *Zea mays* the catalase ratio and percentage germination of the unirradiated lot are 2.1 and 61.1, respectively. But both of these values increase, the former to 3.2 and the latter to 84.2, when the seed is previously irradiated for 1 minute. Further increase in the duration

[1]Contribution from the Institute of Agricultural Research, Benares Hindu, University, Benares, India. Received for publication July 11, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 1016.

[4]The set up of the tube used in this work is as follows: Voltage = 54 K.V.; tube current = 5 ma; distance 15 cm; anticathode = tungsten; duration of irradiation = 1, 2, and 5 minutes.

of dosage brings about an inhibiting effect in the two directions. This trend is initiated only slightly, by irradiation for 2 minutes as indicated by the fact that subsequent to this pretreatment neither the catalase ratio nor the germination percentage fall below normal. On the other hand, a definite deletarious effect follows a still longer exposure (5 minutes) to X-rays. The catalase ratio in this case falls below unity and the germination percentage decreases to only 43.

TABLE 1.—*Catalase ratio and germination percentage of crop seeds following treatment with X-rays for varying lengths of time.**

Untreated seed		Seed irradiated for					
		1 minute		2 minutes		5 minutes	
Catalase ratio	Germination, %	Catalase ratio	Germination, %	Catalase ratio	Germination, %	Catalase ratio	Germination, %
Zea mays var. Jaunpur Yellow							
2.1	61.1	3.2	84.2	2.3	65.2	0.9	43.0
Triticum vulgare var. P. 165							
2.2	63.4	2.5	76.6	1.9	59.1	1.4	45.8
Cicer arietinum var. P. 46							
1.1	52.6	1.6	64.4	1.2	55.0	1.0	46.2
Carthamus tinctorius var. Benares Local Thornless							
1.5	58.8	1.6	61.8	1.9	70.4	1.2	54.0

*As the ratio was required and not the actual amount of oxygen liberated from H_2O_2, the ratio of manometric lengths only was calculated. The germination counts were made on a lot of 500 seeds in each case.

Triticum seeds irradiated for 1 minute gave a higher catalase ratio and a higher germination percentage (Table 1) than corresponding values from normal samples, but as before, with a further increase in the duration of exposure, a progressive fall in quotient value is observed and this finds an ultimate expression in terms of poor germination of seeds. In *Cicer*, the catalase ratio and germination percentage of the control lot are 1.1 and 52.6, respectively. After the seeds were irradiated for 1 minute both the ratio and germination increase considerably over the control, while longer pretreatment caused a depressing effect. In *Carthamus*, however, even a relatively heavy dose of 2 minutes duration finds favor both with regard to catalase ratio and germination capacity. Still longer exposures (5 minutes), however, cause an inhibiting effect in the case of the seed of this crop.

CONCLUSIONS

Obviously, different types of seeds possess differential susceptibility to X-rays which finds expression in the germination phenomenon. The intimate association and interdependence of catalase ratio and

germination capacity of seeds are greatly stressed by their identical behavior in several crop seeds differing widely in their biochemic constitution. Thus, if germination could yield a true value of pre-sowing treatment, the same could equally well be pictured in the catalase ratio with the advantage that it could be applied at a far earlier stage in the seed to seed life-span.

As soon as a dormant seed is given suitable conditions, it begins to develop vigorously. Such a seed on casual inspection remains in a resting state until the seedcoat actually bursts open and allows the embryo to emerge. For want of a measure, therefore, the treatment response ordinarily remains obscure until the so-called germination is complete. It is anticipated that as a sensitive test of the metabolic status of tissues and as a more or less precise indicator of the physiological responses of developing seeds to pre-sowing treatments like irradiation, the catalase ratio may serve as a useful guide in some agronomic practices.

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GROWTH HABITS OF REED CANARY GRASS[1]

MORGAN W. EVANS AND J. ELBERT ELY[2]

THIS paper describes the growth of the plants of reed canary grass (*Phalaris arundinacea* L.). It deals only with the vegetative development of the plants. No study was made of the formation and fusion of the gametes, nor of the development of the seed.

EARLY GROWTH OF THE PLANT

A grass seedling is composed of the primary shoot only. After branches develop or the internodes of the culm become elongated, it is no longer a seedling (5, page 2).[3] As the young plant continues its growth, branches eventually develop from its nodes. They may occur either as above-ground leafy shoots or else as underground rooting stems or rhizomes.

In experiments conducted at North Ridgeville, Ohio, very little difference was observed in the time required for germination of reed canary grass and other grasses. From seed of reed canary grass sown on April 20, 1936, the first seedlings appeared above the surface of the soil on April 29, one day later than the first seedlings developed from timothy sown on the same date.

RHIZOMES

New rhizomes develop in the largest numbers during the months of May, June, July, and August. Relatively few begin their growth during the early spring or the fall months, when leafy shoots develop in the greatest numbers. They originate in the largest numbers from buds at nodes of older rhizomes near the juncture with their terminal shoots. They also grow, in smaller numbers, from buds at nodes in the horizontal part of the rhizomes at some distance back from the apical shoot. Rhizomes occasionally develop near the base of the above-ground shoots from buds in the axils of leaves.

When rhizomes are continuing growth as such, they grow in a generally horizontal direction. When the time approaches for the development of a leafy shoot from the growing point of any rhizome, it turns upwards, as illustrated in Fig. 1, frequently quite abruptly,

[1]This investigation was begun and most of the data were obtained at the Timothy Breeding Station, North Ridgeville, Ohio, conducted cooperatively by the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, and the Department of Agronomy, Ohio Agricultural Experiment Station, Wooster, Ohio. After the work at the Timothy Breeding Station was discontinued, additional data were obtained both at North Ridgeville and at Wooster. Also presented before the Botanical Section of the Ohio Academy of Science meetings at Cleveland, Ohio, May 9, 1941. Received for publication July 14, 1941.

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[3]Figures in parenthesis refer to "Literature Cited", p. 1027.

toward the surface of the soil. In July, August, September, October, and November of 1932, the percentages of rhizomes curved upwards at their apices were 22, 26, 27, 41, and 56, respectively.

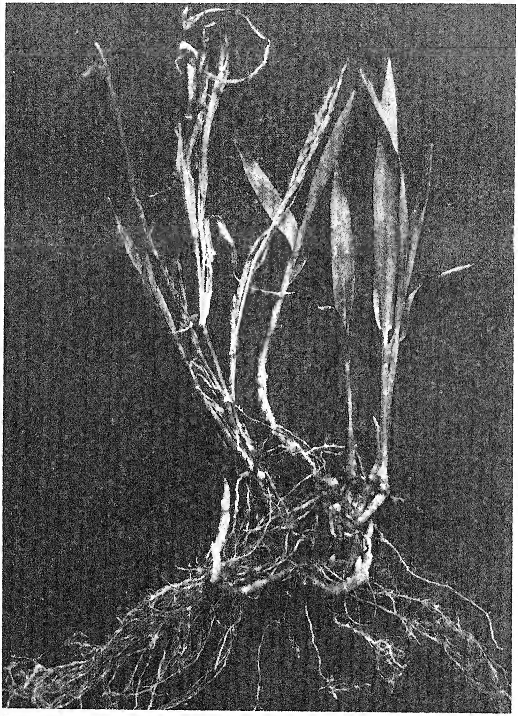

Fig. 1.—Photograph May 7, 1934, of a plant of reed canary grass. Two rhizomes which had grown outward from the plant in a horizontal direction have turned upwards and are about to terminate in leafy shoots.

On a number of reed canary grass plants growing in row plots which were examined in 1935, the maximum depths of growth of any rhizome

was 6 inches. Some rhizomes were growing near the surface of the soil and the average depth of these was approximately 2 inches.

In an earlier study (7) it was found that the average length of the rhizomes of reed canary grass was 1.6 inches. The lengths of the rhizomes were less than on plants of *Poa pratensis* L. or *P. compressa* L. and much less than on plants of *Agropyron repens* (L.) Beauv.

The rhizomes tend to grow toward a place in the soil where competition is less from other rhizomes and roots. As this process continues, the area occupied by a plant gradually expands, as illustrated in Fig. 2. From these rhizomes new shoots develop. In June, 1935, in

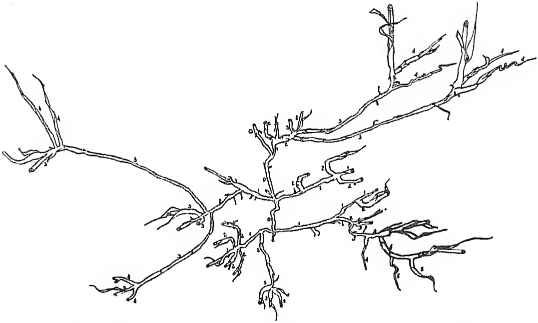

FIG. 2.—Map made on May 21, 1937, of the different generations of rhizomes of a reed canary grass plant transplanted April 14, 1936, with short section of rhizome attached. The original shoot with rhizome is marked "O". The maximum distance across this plant, at the surface of the soil, was 11.0 inches.

reed canary grass plants which had been transplanted in October, 1932, there were no areas occupied exclusively by dead shoots and leaves.

ROOTS

Reed canary grass roots grow from the nodes of rhizomes and from the basal nodes of their terminal shoots. A branch shoot which grows from a node on a culm above the surface of the soil, however, must continue to obtain its nutrients through the roots of the parent shoot.

ABOVE-GROUND SHOOTS

In 1936, on plants growing in cultivated row plots, an average of approximately 74% of the shoots developed from rhizomes and 26% from buds in the axils of basal leaves of above-ground shoots.

New shoots develop in the largest numbers during the autumn and early spring. During late spring and summer, when the rhizomes are developing in large numbers (7, page 792), relatively few new shoots

appear. Thus, on plants transplanted in May, 1931, in cultivated row plots, the average number of new shoots in 1933 was as follows: April, 40; May, 30; June, 1; July, 3; August, 45; September, 97; October, 117. The greater number in the fall than in the spring may be attributed, in part, to the increasing size of the plants as they became older.

SHOOTS WITH AND WITHOUT INFLORESCENCES

On two typical plants grown from seed which had been transplanted to cultivated row plots in October, 1932, an average of 44 elongated shoots with and 28 without inflorescences per plant were observed on August 4, 1934. On the same date, on four typical areas in a broadcast plot which had been sown in the spring of 1929, an average of five elongated shoots per square foot with and 37 without inflorescences were counted. Under the favorable conditions for the 2-year-old plants in the cultivated rows, 61% of the shoots with culms produced inflorescences; while under the less favorable conditions in the 5-year-old broadcast stand, this percentage was reduced to 12. In reed canary grass, therefore, as in timothy (5, pages 13–16), the proportion of shoots which produce inflorescences increases as the cultural conditions improve.

The proportion of inflorescences also depends upon the time the shoots begin growth. On plants in cultivated rows on a number of shoots, each with six leaves, marked for observation on November 18, 1931, 67% produced inflorescences in the following season. On the same plants, a number of younger shoots, each of which had only two leaves on May 12, 1932, produced no inflorescences.

ELONGATION OF THE INTERNODES OF THE CULM

About the middle of April, in the latitude of northern Ohio, the internodes of the developing culms of reed canary grass begin to elongate.

In the summer of 1936, 17 shoots with inflorescences were examined. There were five shoots with 8, five with 9, five with 10, and two with 11 elongated internodes. The average number was approximately 9 (9.2). Not infrequently the number of internodes may be greater. In these culms having 9 elongated internodes, the average lengths of which from the basal to distal ends of the culm were 0.3, 1.1, 2.9, 3.7, 3.6, 3.1, 4.4, 6.3, and 11.5 inches, the last measurement including the inflorescence as well as the uppermost internode of the culm.

COMPONENT PARTS OF THE SHOOT

On each of five dates in 1936, 75 typical shoots of reed canary grass each with seven leaves and an inflorescence were harvested at approximately 2.5 inches above the surface of the soil. The inflorescences were cut off at the juncture of the rachis and culm, and each leaf-blade was cut at its juncture with the sheath which was left attached and therefore contributed to the weights of the culm. The average air-dry weights for all dates of the component parts of these shoots were as follows: culms, 298.2 grams, or 79.4% of the total weight;

inflorescence, 18.5 grams, or 4.9%; leaf blades, 58.8 grams, or 15.7%; total, 375.5 grams. A gradual decrease was shown from 70.6 to 45.0 grams, or from 17.0 to 12.7% of the total weight, from June 23 to July 20 in the weights of the blades of the upper 7 leaves of these shoots. The average weights of the inflorescences also decreased from 25.6 grams on June 23 to 14.8 grams on July 20, or from 6.2 to 4.2% of the total air-dry weights of the cut shoots, due chiefly to the loss of seed through shattering.

If the shoots of reed canary grass are left uncut during late summer, branches develop from buds at their nodes. The shoots continue their growth during the late summer and fall and some leaves remain green until destroyed by freezing weather. In the summer of 1935, branches began to develop about the middle of July. No new branch appeared after August 15. On each shoot there were from two to five branches, most of which developed from the second or third node below the inflorescence. Again, on plants examined July 31, 1937, each shoot with an inflorescence had an average of 2.9 branches; on the same plants each shoot without inflorescences had an average of only 0.3 branch. When these plants were re-examined on August 31, only a very slight change in the number of branches per shoot was apparent. On those shoots without inflorescences, new leaves continued to appear at intervals throughout the season on their central axes, but a smaller number of branches developed on them than on the shoots terminated by influorescences.

PERIOD DURING WHICH A SHOOT CONTINUES ITS GROWTH

If a shoot begins growth in the spring or early summer, its internodes become more or less elongated, its growing point is pushed up to an exposed position above the surface of the soil, and its life is limited to the same season in which its growth began. If, on the other hand, a shoot begins growth in the autumn and if, during the winter, its internodes are not at all or only very slightly elongated so that its growing point remains at or below the surface of the soil, it ordinarily survives and its period of life may extend over slightly more than one year.

THE LEAVES

On the culms of reed canary grass shoots with inflorescences, the number of leaves commonly varies from about seven to nine. The total number of leaves per stem, including those on the nonelongated part of the stem below the culm, is somewhat greater. In a series of records obtained in 1932, the average total number of leaves per stem was 15.7. On the culms of shoots without inflorescences, the total number of leaves may become about 20 or possibly more.

As shown in Table 1, on shoots bearing inflorescences on June 16 all of the four uppermost leaf-blades were entirely green, a large proportion of leaves Nos. 5 and 6 were partially green, and practically all blades of leaf No. 7 had become entirely brown. As the season advanced, more of the leaves gradually became dry and brown, though even as late as July 20 some entirely green blades were present and most of the four upper leaves had blades at least partially green.

TABLE 1.—*Record of the condition of the leaf blades of reed canary grass on culms with inflorescences collected on five dates in 1936.*

Leaf No. and condition*	Percentage of green, part green and part brown, or brown blades on					
	June 16	June 23	June 29	July 7	July 14	July 20
1; G	100	100	96	100	55	37
G-B	0	0	4	0	36	30
B	0	0	0	0	9	33
2; G	100	100	100	100	89	34
G-B	0	0	0	0	11	63
B	0	0	0	0	0	3
3; G	100	100	85	93	53	10
G-B	0	0	15	0	47	82
B	0	0	0	7	0	8
4; G	100	100	35	53	23	12
G-B	0	0	65	44	73	65
B	0	0	0	3	4	23
5; G	54	56	0	12	4	0
G-B	46	44	87	58	47	28
B	0	0	13	30	49	72
6; G	9	0	0	0	0	0
G-B	34	71	35	13	5	3
B	57	29	65	87	95	97
7; G	0	0	0	0	0	0
G-B	1	0	0	0	0	0
B	99	100	100	100	100	100

*Leaf No. 1 is the uppermost leaf next to the inflorescence. G indicates the blade is entirely green; G-B, partially green, partially brown; and B that it is brown. The stages of development of the inflorescences on each date when shoots were collected were as follows: June 16, past full bloom; June 23, inflorescences turning straw color near tips; June 29, all inflorescences straw color and seeds beginning to shatter; July 7, nearly all seeds shattered; July 14, all seeds shattered; July 20, all seeds shattered.

THE INFLORESCENCES

The lower part of the growing point of reed canary grass is divided into segments or phytomers, each surmounted by a slight ridge extending around it, as shown in Fig. 3A. Each ridge is the primordium of a leaf. New phytomers, or plant units, form from the apical meristem at somewhat more frequent intervals than leaves develop. Consequently, as the vegetative shoot becomes older, there is a gradual accumulation of rudimentary phytomers, as illustrated in Fig. 3B.

Usually the inflorescence begins to develop either at about the time of, or just before, the internodes of the culm begin to elongate. In the latitude of northern Ohio this occurs about the middle of April. The earliest lateral protuberances, i.e., the secondary ones, develop in the upper middle part of the growing point, as indicated in Fig. 3C. Each protuberance is the homologue of a vegetative bud (8, page 492). Afterwards, additional secondary protuberances develop in progression both acropetally and basipetally.

As reproductive development progresses, tertiary protuberances like those shown in Fig. 3D develop on the axis of each secondary one in a plane at right angles to the plane in which the secondary protuberances are arranged on the primary axis. From some of the tertiary protuberances quaternary ones may form. In each of the three groups of protuberances shown in Fig. 3E, all of the protuberances have developed from a single secondary one. It is in this way that a group of branches at each node of a mature inflorescence originate.

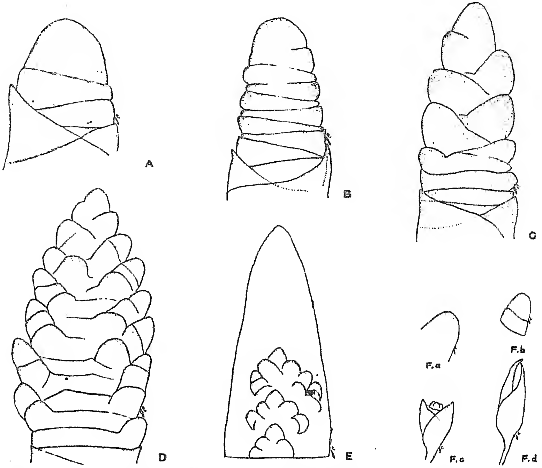

FIG. 3.—The vegetative growing point of the shoot and the rudimentary inflorescence of reed canary grass. A, The vegetative growing point of a young shoot viewed from right angles to the plane of the leaves. B, The growing point of a shoot showing an advanced stage of vegetative development. C, The rudimentary inflorescence beginning to form, with several secondary protuberances. D, A young inflorescence, with several tertiary protuberances forming on the older secondary ones. E, Outline drawing of a rudimentary inflorescence viewed in the same angle as the leaves of the shoot. Protuberances of second, third, and fourth order shown in detail. F, Different stages in the development of a spikelet: (a) Protuberance; (b) a protuberance with a slight ridge which represents the beginning of the lower glume; (c) a rudimentary spikelet with the beginning of the two glumes, a lemma, and three stamens surrounding the growing point; elongation of the stem taking place; (d) all parts of the spikelet enclosed by glumes.

Within about 3 weeks after the first protuberances have developed, the formation of new ones ceases. From each protuberance, eventually a spikelet usually develops as indicated in Figs. 3Fa to 3Fd.

Flowering habits and seed production.—The time when blooming is about to begin is indicated, sometimes a day in advance, by the upper branches spreading outwards. Soon after the last florets have passed out of bloom on any branch, it again folds to its original appressed position.

During the period of bloom, the florets of reed canary grass, as in timothy (4) and other grasses, bloom each day, except when weather conditions are unfavorable. When temperatures are unseasonably low, especially if there is little sunshine or if rainfall occurs, no florets may bloom for one or two days and occasionally for an even longer time. After being repressed for a few days, the florets tend to resume blooming; even under slightly unfavorable conditions. These observations correspond with those obtained by Fruwirth (9), who found that when potted plants of *Arrhenatherum elatius* (L.) Mert. and Koch., *Festuca pratensis* Huds., and *Dactylis glomerata* L. were placed during the blooming period in a damp dark room with a temperature of 7.4° C (45.3° F), flowering was suppressed for 1-, 2-, or 3-day periods. When the plants were placed in the sunshine, the florets bloomed, sometimes beginning within 2 or 3 minutes, and at hours when under normal conditions this would not occur.

On plants growing in row plots of ordinary commercial reed canary grass, the dates when the first florets bloomed ranged from June 12 to 18 in 1935 and from May 28 to June 14 in 1936. The mean date when the first florets bloomed was 9 days earlier in the latter than in the former year. The records from the Cleveland Weather Bureau Station show during April, May, and June in 1935, the mean monthly temperature was 2.4° F below normal and that in 1936 it was 0.6° F above normal. These records indicate that in reed canary grass, as in timothy (6) and in certain other plants representing a wide range of types (10), cool temperatures delay and high temperatures hasten the time of blooming.

The ripening process, like that of flowering, begins in the upper part of the inflorescence, progressing toward its base. On the inflorescences observed at North Ridgeville, Ohio, on June 23, 1936, glumes were becoming straw color only in the uppermost parts of the inflorescences, while those below were still green. Six days later the earliest seeds were beginning to shatter. The seeds shatter almost as soon as fully ripe (11); and as a result, some of the seeds in the upper part of an inflorescence ordinarily shatter before those near its base mature (2, 3).

PROTEIN CONTENT

On different dates in 1937 samples of reed canary grass hay were collected for nitrogen analysis. The percentages[4] of protein were as follows: On May 20, 16.2; May 28, 12.3; June 4, 9.4; June 11, 7.2; June 18, 6.6; June 25, 6.0; July 2, 5.8; and July 13, 6.6.

In 1936, the analyses recorded in Table 2 were made on six dates

[4]The records presented are on a moisture-free basis. They were obtained by multiplying the percentages of nitrogen by 6.25. On the same dates, samples of ordinary timothy hay, collected from another meadow, contained 10.1, 9.5, 7.4, 7.6, 6.0, 6.6, 5.1, and 6.3% of protein, respectively.

from June 16 to July 20 of the percentages of protein in the culms, the inflorescences, and the leaf-blades of shoots. The condition of these leaves, i.e., whether they were entirely green, partly green, or brown, is shown in Table 1. As the proportion of brown leaf tissue increased, the percentage of protein decreased.

TABLE 2.—*Percentages of protein on a moisture-free basis in the culms, inflorescences, and leaf-blades of reed canary grass on different dates in 1936.**

Plant part	June 16	June 23	June 29	July 7	July 14	July 20
Culms	—	2.8	2.6	3.1	3.6	3.6
Inflorescences	—	10.7	6.8	5.5	5.4	4.9
Leaf-blade:						
No. 1	14.8	14.5	13.0	13.9	12.4	9.1
No. 2	16.8	17.6	13.4	14.4	14.6	13.4
No. 3	17.2	15.1	14.8	14.4	13.4	11.5
No. 4	14.8	15.1	12.5	12.2	10.7	8.7
No. 5	12.8	12.5	9.1	9.2	7.6	6.1
No. 6	8.8	9.9	5.5	6.1	7.3	4.7
No. 7	4.9	4.0	4.0	3.7	5.9	4.3

*These analyses were made by the Department of Agronomy of the Ohio Agricultural Experiment Station. Leaf No. 1 is immediately below the inflorescence, No. 2 is the second below the inflorescence, etc. The leaf sheaths were left attached and are included in the analyses of the culms.

WINTER INJURY

According to Alway (1), Retzius stated in 1806 that in many places in Swedish Lapland reed canary grass was thought to give the heaviest yield and the best quality of forage of all of the grasses cut for hay. It is sufficiently hardy, therefore, to survive winter conditions in northernmost Europe. At College, Alsaka, however, at 64 degrees and 51 minutes north latitude, Gasser[5] has observed that brome grass (*Bromus inermis* Leyss.) is winterhardy, while reed canary grass is not.

At North Ridgeville, Ohio, after winters of unusually severe freezing during which the leaf tissues of other grasses were not seriously injured, the leaves on shoots of reed canary grass were frozen nearly or quite down to the surface of the soil. From April 12 to 14, 1932, after spring growth had begun, the temperatures were abnormally low. At the United States Weather Bureau Station at Cleveland, approximately 20 miles east of and at about the same elevation as North Ridgeville, the daily minimum temperatures ranged from 25° to 30° F. The mean temperatures were from 10° to 14° below normal for these dates. On shoots of reed canary grass, the tips of many of the leaves which had grown earlier in the spring were frozen. None of the other grasses examined, including bromegrass (*Bromus inermis*), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*P. pratensis*), quack grass (*Agropyron repens*), redtop (*Agrostis alba* L.), and timothy (*Phleum pratense* L.), had any apparent injury to the leaf tissue as a result of these unseasonably low temperatures.

Relation of the position of the growing point of the shoot to winter-

[5]Letter from Director C. W. Gasser of the Alaska Agricultural Experiment Station, March 3, 1936.

hardiness.—In 1933, in each month from May to November, all new shoots, i.e., those having three leaves or less, on each one of 12 plants of reed canary grass were labeled. On April 2, 1934, it was observed that all new shoots which had been marked in September, October, and November were growing. No shoots which had been marked earlier than September 15 in the preceding year had any evidence of life. On shoots which begin their growth during the spring or summer months, the internodes become elongated to such an extent that the growing points are pushed up to an exposed position where they fail to survive the winter (5, page 10).

On December 9, 1935, new shoots of reed canary grass, each having three leaves or less, were labeled. On March 12, 1936, six of these shoots were dissected and examined. On one of them the growing point was only 9 mm, and on each of the five others it was from 1.4 to 3.2 cm below the surface of the soil. The elongation of the axes of these shoots had not been sufficient to push the growing points up above the surface of the soil. It is through these younger shoots, with their growing points in a protected position beneath the soil surface that the plant survives the winter.

SUMMARY

The underground rooting stems or rhizomes of reed canary grass (*Phalaris arundinacea* L.) originate chiefly during May, June, July, and August, usually from buds in the axils of scales of older rhizomes near the juncture of the rhizome with its terminal shoot. Above-ground shoots develop in largest numbers during fall and early spring from the apices of rhizomes and from axillary buds. In the latitude of northern Ohio, culms, with their elongated internodes, begin to form about the middle of April. The proportion of shoots producing inflorescences increases with improved cultural conditions. The life of a shoot which develops from a bud in the spring is limited to the same season, and the life of one which develops in the fall is limited to the growing season of the following year.

The tips of the leaves on the culms begin to turn brown during the latter part of July and in early August, but the blades of some of them may remain partially green until freezing weather. During late summer and fall, on both fertile and barren shoots, the number of green leaves on any culm becomes augmented by those on branches which develop at nodes between the elongated internodes of the culm.

In the latitude of northern Ohio, inflorescences begin to develop from the growing points of the shoots about the middle of April, flowering begins in early June, and seeds mature in late June and early July. Until the process is completed, flowering occurs each day except when interrupted by cool, cloudy, or rainy weather. Flowering and maturing gradually progress from just below the tip of the inflorescence toward its base.

As the proportion of green leaf tissue decreases, the percentage of protein gradually decreases.

The leaves of reed canary grass are destroyed by temperatures not low enough to destroy the leaves of timothy, redtop, Kentucky

bluegrass, and some other northern meadow and pasture grasses. Shoots which begin their growth in the spring and summer are not winterhardy. On those developing from buds on rhizomes during the fall months, the growing point usually remains during the winter in a protected position slightly below the surface of the soil and the shoots survive.

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FIELD PERCOLATION RATES OF FOUR WISCONSIN SOILS HAVING DIFFERENT DRAINAGE CHARACTERISTICS[1]

Lewis B. Nelson and R. J. Muckenhirn[2]

THE rate of intake of water into the soil, or the infiltration capacity, is one of the primary factors affecting the amount of surface run-off in the field. The infiltration rate is ordinarily at its maximum when water is first applied to the soil, and then as the pore spaces become filled and swelling occurs, it decreases until a more or less stable minimum is reached. This minimum is the field percolation rate, that is, the rate at which water moves through the saturated soil profile, and it is governed largely by the permeability of the least pervious horizon. This minimum or stable infiltration rate or percolation rate, being a quantitative determination of the rapidity with which water can move through a saturated profile, is a measure of the internal drainage.

This rate controls soil water movement when water is abundant, as during periods of prolonged precipitation, or during the early spring when the soil is saturated as a result of thawing, spring rains, and low evaporation. This rate is not necessarily important in establishing the rate of run-off and erosion during the drier summer period when only the upper portion of the soil is likely to be saturated by any one rain.

In Wisconsin, as in other mid-western glaciated states, the internal drainage of several soil types is a major factor controlling the kind of crops adapted to these types. Perhaps the outstanding examples in Wisconsin are the Spencer (Colby) and Marathon silt loams in the north-central portion of the state (9).[3] These two soils occur side by side and are often intermingled, yet, because of the effect of different substrata and degrees of post-glacial erosion upon their profile development, the former has poor while the latter has good internal drainage. On the poorly drained Spencer, such crops as alfalfa and potatoes usually fail, but they are well adapted to Marathon soils. The Spencer is subject to frost heaving, is cold and wet, and is late in reaching a tillable condition in the spring, while the Marathon in the same neighborhood does not show these unfavorable characteristics.

Since the crop adaptations of these soils were correlated with internal drainage conditions, quantitative measurements of percolation rates were desired. These measurements, made by a buffer compartment method, were compared with the porosity and percolation rate of cores from the various horizons of these soil profiles, and similar studies were made of two other widely different soils, the Miami silt loam and the Superior clay loam.

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[1]Contribution from the Department of Soils, University of Wisconsin, Madison, Wis., and published with the permission of the Director of the Wisconsin Agricultural Experiment Station. Received for publication July 19, 1941.

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[3]Figures in parentheses refer to "Literature Cited", p. 1036.

METHODS

In general, methods for measuring the initial or short-time infiltration rates can be used in experiments of long duration for measuring the final or stable percolation rate. For infiltration measurements, one of two methods (3) has been generally used. In the Musgrave method, water is applied to the surface of a cylinder of soil enclosed by a steel cylinder which has been pushed into the soil. In the buffer compartment method, a shallow, inner, metal ring is surrounded by other rings and water is applied to the same depth in all the enclosed compartments. The outer compartments supply water for lateral flow and for downward movement directly underneath, so the inner ring, the only one from which measurements are taken, is theoretically unaffected by lateral movement. The buffer compartment method apparently was first devised by Nesterov (2) and has been previously adapted to particular purposes by Katchinsky (2), and Kohnke (3).

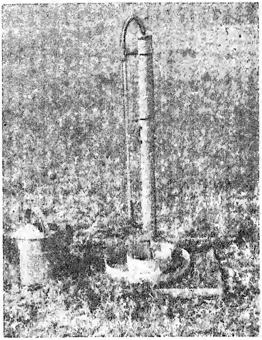

FIG. 1.—Buffer compartment apparatus used in making field percolation measurements.

In the earlier part of the present investigation, the cylinder infiltration method of Musgrave (4) and Musgrave and Free (5) was used. A battery of 8 or 10 steel cylinders 8 inches in diameter and 14 inches long were forced 12 or 13 inches into the soil by jacking against a heavy tractor. A ¼ inch head of water was maintained on the soil surface in each cylinder by means of a self-dispensing calibrated 3,000-cc burette similar to that used by Stauffer (8), Readings were taken at 15- and 30-minute intervals in the early part of the run and thereafter at hourly intervals. The cylinder method gave inconsistent results for reasons discussed below and was therefore abandoned.

The following buffer compartment method, in which two concentric rings filled with water prevented lateral movement of water from the inner measuring ring, was then tested and adopted. The apparatus used (Fig. 1) consisted of a galvanized iron ring, having an inside diameter of 8 inches and a height of 5 inches, surrounded by another ring having an inside diameter of 16 inches and a height of 3 inches. These rings were driven into the ground 1 or 2 inches and were surrounded by an additional guard, 24 inches square, made of lath and spiked to the ground. A third metal ring of similar diameter would have been preferable to lath. A ¼-inch head of water was maintained on all of the enclosed soil areas. The water added to the central ring was measured by means of a 3,000-cc burette used in the previously described cylinder method, but manual addition of water from measuring cylinders is equally satisfactory. The use of an automatically recording scale or float with dispensing burettes or other water containers would be ideal for long-continued measurements. During the first 1 or 2 hours readings were made at 30-minute intervals and thereafter at the end of every hour. The run usually consisted of eight consecutive hours during the day followed by an

overnight period when no water was applied. The total period of actual water application consisted of 20 hours or more covering a period of 3 days or more. Usually, if the same reading was obtained for 5 or 6 consecutive hours toward the end of the run, this was considered as being the true percolation rate of the soil profile. The determinations were made in quadruplicate for each set-up.

The laboratory percolation rate, volume weight, porosity, and maximum water-holding capacity determinations were all made on the same sample by employing the cylinder method as described and used by Sell (7) in volume weight studies. The procedure consisted of carefully driving a seamless steel cylinder, 4 inches in diameter and 3 inches long, horizontally into the desired soil horizon. The cylinder and core were removed from the profile by digging, and the soil protruding from the top and bottom of the cylinder was cut off with a sharpened putty knife. The encased core was then immersed in a water bath for 12 hours or longer, permitted to drain for 2 hours, and weighed. This initial weight and the final oven-dry weight were used in calculating the maximum water-holding capacity of the core. A coarse filter paper and a 20-mesh wire screen were then fitted over the bottom of the cylinder, a piece of inner-tubing placed around the top, and the entire apparatus placed on a large funnel which drained into a graduated cylinder. A ¼-inch head of water was maintained over the top of the core by means of the inner-tube encasement, and the percolate was measured and reported in surface inches per hour. After duplicate or triplicate percolation measurements were made, the core with cylinder was dried to constant weight in an oven at 105° C. The volume weight and the percentage porosity were calculated according to standard formulas.

DESCRIPTION OF THE SOILS

The Spencer silt loam, subdivided into a level and a rolling phase, occupies an area of about 5,000 square miles in north-central Wisconsin. The surface soil is a friable, grayish-brown silt loam and is underlain by a strongly-mottled, reddish-brown, silty clay subsoil which is very compact, tightly cemented, and seldom penetrated by plant roots. The parent material is a sticky, impervious sandy clay deposited by one or more early, pre-Wisconsin glaciations, although it appears that some silt was deposited on the surface. This soil has the poorest internal drainage of any upland type in the state. This condition has been ascribed either to the presence of deep, heavy till underneath or to prolonged weathering, lack of erosion, and accumulation of colloids.

The Marathon silt loam has developed from the same parent material as the Spencer, but in locations where the parent till is shallow. It occupies a total area of about 360 square miles adjacent to and intermingled with the Spencer. The Marathon occurs on rolling topography wherever approximately 3 feet or less of drift now overlie decomposed, coarse-grained, porous, igneous bedrocks, generally of granitic composition. Its profile differs distinctly from that of the Spencer, particularly by its lack of mottling, and by the presence of a shallower, less strongly cemented and more pervious B_2 horizon which is easily penetrated by plant roots. In the Marathon, the shallower depth of till, consequent nearness of the underlying, permeable bedrock, and the normal erosion on sloping land have prevented the excessive illuviation and impermeability of the Spencer soil. A detailed discussion of the origin and development of the Marathon and Spencer soils has been given in another paper (6).

The Superior clay loam occurs on the Lake Superior Lowland in the extreme

northwestern portion of the state. The parent material from which this soil developed was laid down in old glacial lakes and portions were then slightly reworked by ice. The more level areas of this soil type are frequently poorly drained because of the impervious nature of the deeper horizons and the underlying parent material. The surface layer is a pinkish, silty clay loam which is usually well granulated and strongly acid. Below this, the soil grades into a red clay which in turn is gradually replaced by a less-weathered, less-acid, lighter colored red clay.

The Miami silt loam is a well-drained soil, occurring extensively in southeastern Wisconsin. This soil was derived largely from calcareous glacial till of the Third Wisconsin Glaciation, although some loess probably covered the till. The cultivated surface soil is a grayish brown, friable silt loam, and is underlain by a brown, clay loam subsoil having a distinct nutlike structure. This subsoil is easily penetrated by plant roots and is permeable to water.

RESULTS

At the beginning of the investigation, an attempt was made to adapt the Musgrave infiltration method to field percolation studies. The method gave good measurement of the initial intake of water into the soil and of the relative permeability of the soil core enclosed within the cylinder, but could not be relied upon to give quantitative information regarding the permeability and the percolation rate of the entire soil profile. The soil enclosed by the cylinder was found to be completely saturated at the end of 8 hours and further water application merely resulted in movement out of the bottom of the cylinder in all directions into the surrounding soil. In addition, large variations were found to occur in the rate of intake of water between the different units used for each determination. These were caused by damage to soil structure, and by rocks and roots being caught under the edges of the cylinder when it was forced into the soil. Further, it was found to be exceedingly difficult to force the cylinders into the soil, particularly when the soil was not at optimum moisture content.

By using buffer compartments to diminish lateral movement, the Musgrave cylinders probably could be used to determine field percolation rates. However, in the present investigation, it was felt that the difficulties and errors arising from forcing the steel cylinders into the soil were great enough to discourage their use.

The use of the buffer compartment method in field percolation studies was found to possess certain advantages. Lateral movement of water from the central ring was either completely eliminated or greatly diminished. The structure of the soil was not disturbed since the rings were driven only 1 or 2 inches into the soil. In contrast with the long steel cylinders, water channels formed by roots and stones driven downward by the cylinders, particularly in stony soils or sodded fields, were entirely eliminated. The equipment is simple, inexpensive, and easy to transport and install. It can be used both for infiltration measurements and for field percolation studies, and gives more consistent and reproducible results.

The results of field percolation determinations by the buffer compartment method are shown graphically in Fig. 2 for each of the four

soils investigated. These determinations were made on fields of second year alfalfa on uniform soil areas considered typical of each soil type. The determinations were made on the Spencer, Marathon, and Superior soils in August and on the Miami in October. The field moisture contents at the beginning of the determinations were 24% for the plow layer of the Spencer and 17% for its subsoil; and for both the plow layers and subsoils of Marathon approximately 17%, of Superior approximately 20%, and of Miami about 27%.

It is seen from the plotted rates of intake that, although the initial or infiltration rates vary, the minimum or stable percolation rates are constant for each type. The percolation rate is 0.04 inch or less per hour for the poorly drained Spencer silt loam and Superior clay loam, while for the well-drained Marathon and Miami silt loams it is 0.3 inch and 0.5 inch, respectively. An exceptionally high initial infiltration rate is shown for the Superior clay loam, but the impervious subsoil soon causes a rapid decrease in the intake rate. The fluctuations in the rates of water intake were largely the result of variations in daily temperatures. These are particularly noticeable for the Miami silt loam determination which was made in October when the daily temperatures varied greatly.

Cores obtained from individual horizons as previously described were studied in the laboratory. The amount of water percolating through each series of 3-inch cores of the horizons and substratum of the four soils, and their standard errors, are given in Table 1. The standard errors show considerable variation in the laboratory percolation rate among the replicate cores of some of the horizons, particularly in the plow layers. The percolation data show that the B_2 and substratum of the poorly drained Spencer are impermeable to water movement, while the B_2 of the Superior is only slightly permeable and its substratum is impermeable. All layers of the well-drained Marathon profile permit good water movement and the decomposed substratum offers little resistance to water percolation. The well-drained Miami is permeable in all layers. Of particular interest is the extremely high percolation rate of the plow layer of the Superior clay loam.

TABLE 1.—*Laboratory percolation rates of soil cores of four Wisconsin soils.*

Soils	Horizon			
	Plow layer	B_1	B_2	Substratum
Marathon silt loam....	0.52 ± 0.35	0.47 ± 0.13	0.45 ± 0.34	8.6 ± 1.3
Miami silt loam.......	0.98 ± 0.28	0.59 ± 0.028	0.59 ± 0.11	0.43 ± 0.019
Spencer silt loam......	0.54 ± 0.38	0.046 ± 0.003	0.00	0.00
Superior clay loam....	13.2 ± 2.84	——	0.034 ± 0.024	0.00

The volume weights, percentage total pore space, and maximum waterholding capacities are presented in Table 2. The data show the horizons and substratum of the permeable Miami silt loam to have the lowest volume weights, the highest percentage pore space, and the highest water-holding capacities of the soils studied. The B_2

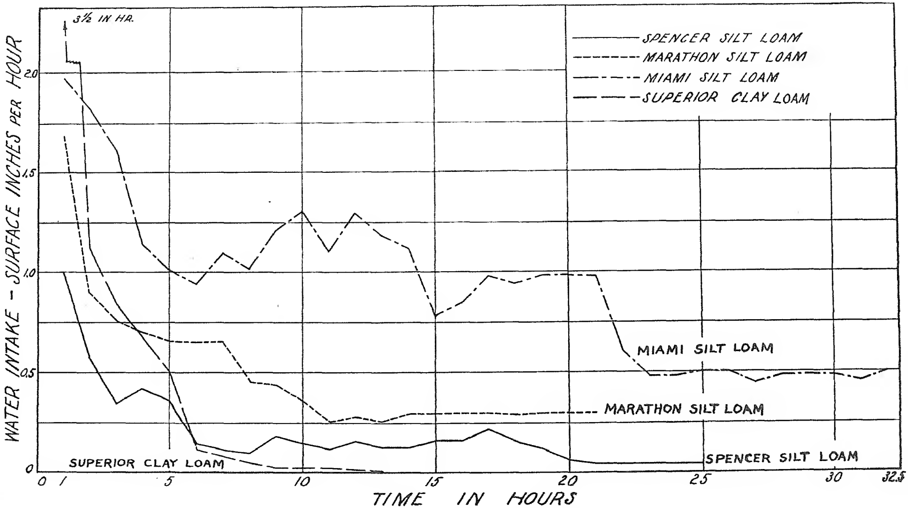

FIG. 2.—The rate of intake of water by four Wisconsin soils during long-continued application with a buffer compartment apparatus. Averages of quadruplicate determinations.

horizons of the poorly drained Spencer and Superior soils are characterized by high volume weights, low pore space percentages, and low water-holding capacities. The data for the parent material and for the B_2 horizon of the Spencer are much the same. The Superior plow layer has a higher volume weight and lower total pore space than is ordinarily expected for a clay loam; however, other determinations on this soil have given similar results. The volume weight and pore space data for the solum of the Marathon silt loam have a more or less intermediate position between those for the Miami and those for the Spencer and Superior. However, the porous granite substratum of the Marathon has a much higher volume weight, lower total pore space, and lower water-holding capacity, as would be expected for material of this nature.

TABLE 2.—*Volume weight, percentage of pore space, and waterholding capacities of soils used in percolation rate investigations.*

Soil	Volume weight	Pore space	Water-holding capacity
Marathon Silt Loam			
Plow layer	1.34±0.021	49.5	33.4±1.33
B_1	1.49±0.023	43.8	24.1±0.98
B_2	1.59±0.017	40.0	20.9±0.54
Parent material	1.72±0.028	35.1	16.7±1.61
Miami Silt Loam			
Plow layer	1.28±0.02	51.7	38.2±0.098
B_1	1.41±0.026	46.8	33.6±0.093
B_2	1.43±0.032	46.0	33.9±1.0
Parent material	1.49±0.0	43.7	30.5±1.76
Spencer Silt Loam			
Plow layer	1.38±0.011	47.0	30.8±0.20
B_1	1.55±0.038	41.5	26.5±1.25
B_2	1.66±0.041	37.4	22.1±1.93
Parent material	1.63±0.029	38.5	22.5±0.73
Superior Clay Loam			
Plow layer	1.46±0.043	44.9	27.5±1.38
B_2	1.68±0.032	36.6	22.5±1.00

DISCUSSION

Inasmuch as noncapillary porosity is a measure of the large pores of the soil which are responsible for the ready percolation of water through the soil, noncapillary porosity measurements (1) would be more desirable in explaining permeability differences than the volume weight, total porosity, and waterholding capacities. However, the latter data indicate that low noncapillary porosities might be expected in the B_2 horizon and parent material of the Spencer and in the B_2 of the Superior. The noncapillary porosities of the Marathon and Miami subsoils probably are chiefly of a noncapillary nature.

Both the field and laboratory percolation rates show the Spencer silt loam to be a highly impervious soil. The laboratory percolation rates of undisturbed soil cores indicate that, when saturated, the B_2 horizon and the underlying clayey till are almost entirely impervious to water movement. The low porosities, low water-holding capacities, and high volume weights point to strong compaction of the B_2 and substratum. The imperviousness of the Spencer profile is reflected by its mottling and poor aeration, its coldness and slow attainment of favorable tillage condition in the spring, its slow rate of intake of surface water after periods of sustained precipitation, and its inability to produce alfalfa and potatoes.

Tile drainage does not remove water with sufficient rapidity because of the tight, compact subsoil of the Spencer. The removal of surface water by means of dead furrows emptying into sodded drainage ways is the only method known to be satisfactory at present.

The Superior clay loam, with its highly pervious, well-granulated plow layer and impermeable subsoil, is a soil having unique drainage properties. As shown by the field percolation studies (Fig. 2), there is a rapid initial intake of water until the pervious plow layer is completely saturated. After this condition is reached, further intake is prevented by the impervious subsoil.

The slow drainage of excess water usually present in the spring makes it necessary to delay the seeding of grain and is responsible for marked reductions in the yields of spring grain (10). The slowness with which the soil drains in spring likewise practically prevents early spring plowing, so cultivated land is usually plowed in the fall.

The Marathon silt loam, with a field percolation rate of 0.3 inch per hour, possesses an intermediate position between the poorly drained Spencer and Superior and the well-drained Miami. The B_1 and B_2 horizons of the Marathon set the limit for the rate of water movement in this soil since the porous granite substratum, with its extremely high percolation rate of 8.6 inches per hour, permits very rapid water movement. This soil is sufficiently pervious and well drained to prevent the mottling, coldness, and delayed drying out in spring which are characteristic of the adjacent and related Spencer. The soil is well adapted to crops sensitive to poorly drained conditions.

The comparatively high field percolation rates of the Miami silt loam are directly correlated with the high laboratory percolation rates of its horizons and substratum. In comparison with the poorly drained Spencer and Superior soils, its volume weights are lower, porosities greater, and water-holding capacities higher, indicating less compaction and cementation. Under Wisconsin conditions, this soil is almost ideal from the standpoint of internal drainage.

SUMMARY

Field percolation rates were determined on undisturbed soil profiles of two poorly-drained and two well-drained Wisconsin soils by means of a buffer compartment method. In addition, laboratory percolation rates, volume weights, total porosities, and maximum water-holding capacities were determined on soil cores taken from the different horizons and substrata of each of the four soils.

The buffer compartment method was found to give good measurement of the field percolation rate of the soil and is believed to possess several advantages over the steel cylinder method which is commonly used in infiltration determinations. The lateral movement of water is diminished by means of buffer compartments, the soil structure is undisturbed, and the apparatus is simple, inexpensive, and very easily installed.

The poorly drained Spencer silt loam and Superior clay loam had field percolation rates of 0.04 inch per hour or less. Percolation through the laboratory cores showed the B_2 horizons and substrata to be practically impermeable to water movement. The impervious subsoils had relatively high volume weights, low total porosities, and low water-holding capacities.

The well-drained Marathon silt loam had a field percolation rate of 0.3 inch per hour, while that of the Miami silt loam was 0.5 inch per hour. The laboratory percolation rates of the subsoils and substrata were over 0.4 inch per hour. In general, the subsoils of these well-drained soils had lower volume weights, higher total porosities, and higher water-holding capacities than did the poorly drained soils.

The results of this study correlate well with the characteristics of the soil profiles and explain to a large extent, the differences in cropping and drainage conditions found on these soils.

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FACTORS AFFECTING THE GERMINATION OF BULBLETS OF BULBOUS BLUEGRASS, *POA BULBOSA*[1]

Vivian Kearns Toole[2]

In 1933, Mrs. Grace Cole Fleischman, formerly of the Cooperative Seed Testing Laboratory, Corvallis, Oregon, requested that a study be made of the factors affecting the germination of bulblets of bulbous bluegrass, *Poa bulbosa L. Poa bulbosa* is a commercial crop in southern Oregon and northern California. Schoth and Vinall[3] describe the plant, its distribution, its uses and value, and its method of forming bulblets, sometimes referred to as bulbils, instead of true seed in the panicle. The plant ceases growth around May 1 to 15 when the bulblets formed in the panicle are mature. The crop is cut for "seed" when approximately 75 to 85% mature to prevent considerable loss by shattering.

MATERIAL AND METHODS

The bulblets for study were furnished by Mrs. Fleischman. The samples were stored after receipt in cloth or paper bags in the laboratory at room temperature unless otherwise indicated.

The bulblets were germinated in duplicate tests of 100 bulblets each at various constant and one alternating temperature in Petri dishes on moistened paper toweling or on soil. The paper toweling was moistened with tap water or with a 0.2% solution of potassium nitrate. The temperature of the 3°, 10°, and 20° C chambers were controlled within 1° of that listed. The temperature of the 5° chamber varied between 2° and 5°.

To prechill the bulblets, they were placed on the moistened substratum in Petri dishes and held at 5° C for 7 to 14 days before transferring to 10° or 20° constant temperatures. The time of counting is computed from the day the seed was placed to prechill.

The germination values summarized in Table 1 and in the figures are based on duplicate tests of 100 bulblets each. In Figs. 1 to 4 an average germination of several samples is given for simplification since the results of the individual samples were comparable.

RESULTS

GERMINATION OF FRESH BULBLETS

Bulblets from the 1935 crop at Medford, Oregon, were received June 24, 1935, and tested two days later at 5°, 10°, and 20° C on substrata moistened with water or with potassium nitrate.

The germination data at 5° and at 10° C show that temperature was the most important factor influencing germination, although potassium nitrate increased germination at either temperature. The

[1]These investigations were conducted in the former Division of Seed Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture. Received for publication July 24, 1941.

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[3]Schoth, H. A., and Vinall, H. N. Bulbous bluegrass. U. S. D. A. Misc. Mimeo. Pub. 1935.

best germination of these fresh bulblets was obtained at 5° when the substratum was moistened with potassium nitrate. However, complete germination of the viable bulblets was obtained in only two cases, samples Nos. 758079 and 758085, under these conditions (Table 1).

TABLE 1.—*The germination in 84 days of fresh bulblets of Poa bulbosa. 1935 crop from Medford, Oregon, received June 24, 1935; test started June 26, 1935.**

Sample No.	Percentage germination at indicated temperatures with specified treatment							
	5° C			10° C			20° C	
	With potassium nitrate	With water	Mean	With potassium nitrate	With water	Mean	With potassium nitrate	With water
758076	75.5	53.0	64.25	13.5	2.5	8.00	0	0
758077	48.0	8.5	28.25	14.5	5.5	10.00	0	0
758078	69.5	39.5	54.50	6.5	0.0	3.25	0	0
758079	92.0	89.5	90.75	49.0	16.5	32.75	0	0
758080	71.0	48.5	59.75	16.5	7.5	12.00	0	0
758081	83.5	58.0	70.75	30.0	6.0	18.00	0	0
758082	65.0	51.0	58.0	24.0	8.0	16.00	0	0
758083	75.5	53.0	64.25	7.5	2.5	5.00	0	0
758084	87.0	66.5	76.75	25.0	6.0	15.50	0	0
758085	93.0	78.0	85.50	37.5	5.5	21.50	0	0
758086	82.5	67.0	74.75	16.5	2.5	9.50	0	0
Mean...	76.59	55.68	66.13	21.86	5.68	13.77	0	0

*Duplicate 100 bulblet tests.

At the end of 28 days the bulblets at 20° showed no evidence of germination. These tests from 20° were then placed at 3°, one dish with water and one with potassium nitrate under blue light and a similar pair under red light. The subsequent germination of the test transferred from 20° C to 3° and of the test held the entire period at 5° is shown in Fig. 1.

The bulblets germinated faster under red light than under blue light, although there was no consistent difference in final or total germination. The difference in final germination at 3° and at 5° would not appear to be due to the slight difference in temperature of these two series. The increased germination at 3° could be due to the 28-day period at 20° before transferring to a low temperature or to the light exposure at 3°.

GERMINATION OF APPROXIMATELY 4 MONTHS' OLD BULBLETS

The bulblets of the bulk samples received in June 1935 were all used in the preceding experiment. In order to test some of this same material at a later date, two separate additional samples were obtained of each of two of the original lots. These samples were tested

soon after receipt in September 1935 at the alternating temperature 5° to 15° C and at 5°, 10°, and 20° C constant temperatures. The effect of prechilling at 5° for 7 and 14 days before germinating at the two higher constant temperatures was also determined. Neither of the three constant temperatures nor the 5° to 15° alternating tempera-

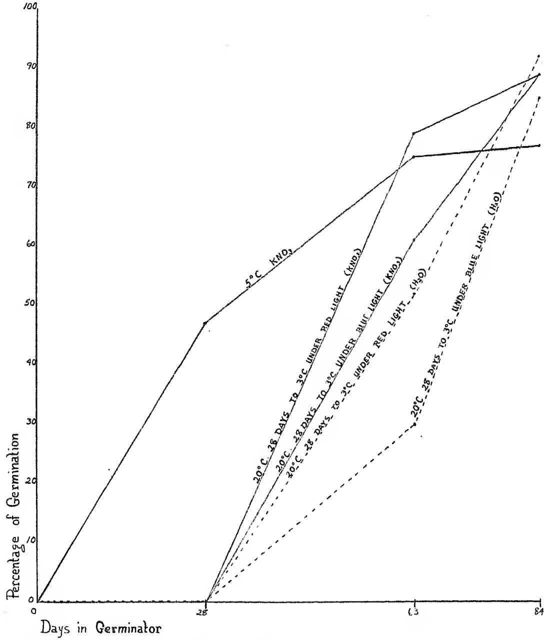

FIG. 1.—The effect of temperature, light, and previous treatment on germination of fresh bulblets of *Poa bulbosa*. (Average of 11 samples.)

ture gave complete germination of the viable bulblets. The bulblets at 5° to 15° and at 10° germinated at a faster rate than at 5°, but the 42-day results at 5° and at 5° to 15° were the same and were markedly better than at 10°. Prechilling the bulblets at 5° for 7 days and then germinating at 10° gave maximum germination. Germination at 20° after prechilling at 5° was 75 to 85% as compared with less than 10% without prechilling. A period of 7 days prechilling was sufficient when

followed by 10° C, but a longer prechilling period was required if the germination temperature was 20° (Fig. 2).

GERMINATION OF 2-YEAR-OLD BULBLETS

Bulblets from the 1931 crop at Medford, Oregon, were received November 14, 1933, and the tests started at 5°, 10°, and 20° C on

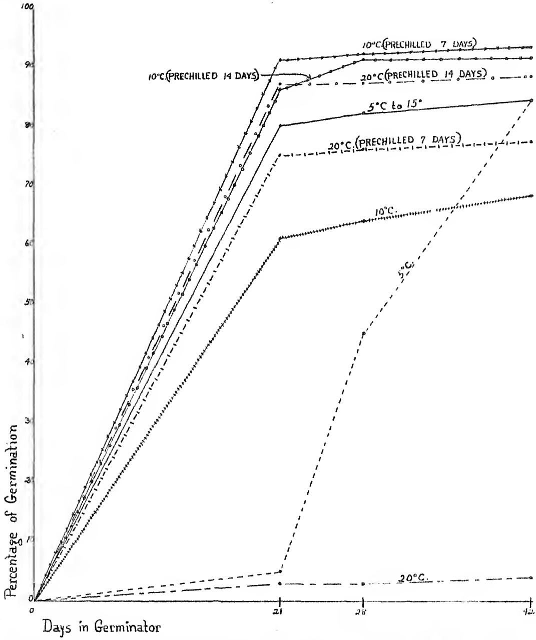

FIG. 2.—The progressive germination in soil in Petri dishes of approximately 4 months' old bulblets of *Poa bulbosa*. (Average of 4 samples.)

November 17, 1933. Germination temperature and the use of potassium nitrate were much less important factors with old bulblets than with fresh bulblets. In contrast to the fresh bulblets discussed previously, these older bulblets germinated readily at 20°. The bulblets germinated much faster at 20° than at 10°, and faster at 10° than

at 5°. In 28 days germination was practically complete at 20° and at 10°, but 3 weeks additional time was required at 5° (Fig. 3).

The differences in results shown between potassium nitrate and water were due to the large number of sprouts with no roots in one of the samples when tested with potassium nitrate. These abnormal sprouts were not included in the percentage of germination.

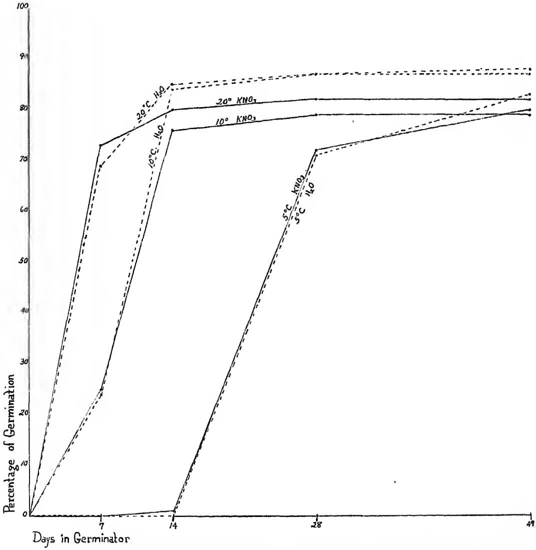

FIG. 3.—The progressive germination of 2-year-old bulblets of *Poa bulbosa* at three temperature conditions. (Average of 3 samples.)

CHANGE IN GERMINATION RESPONSE WITH AGE

Since fresh bulblets germinated progressively better the lower the temperature (from 20° to 5° C) and since old bulblets germinated progressively better as the temperature was raised (from 5° to 20°), an attempt was made to determine the change in temperature response as the bulblets aged.

Samples 758077b and 758080b were tested at 5°, 10°, and 20° C, with and without prechilling treatment in September, 1935, and again in February, 1939. The greatest change in response to temperature occurred at 20°. Germination at 20° was below 10% in 42 days on the fresh bulblets and above 80% in 14 days on the old bulblets. For the

4-year-old bulblets the rate of germination was faster at each of the three temperatures as compared with the rate of the 4 months' old bulblets (Fig. 4). Prechilling the fresh bulblets was essential for

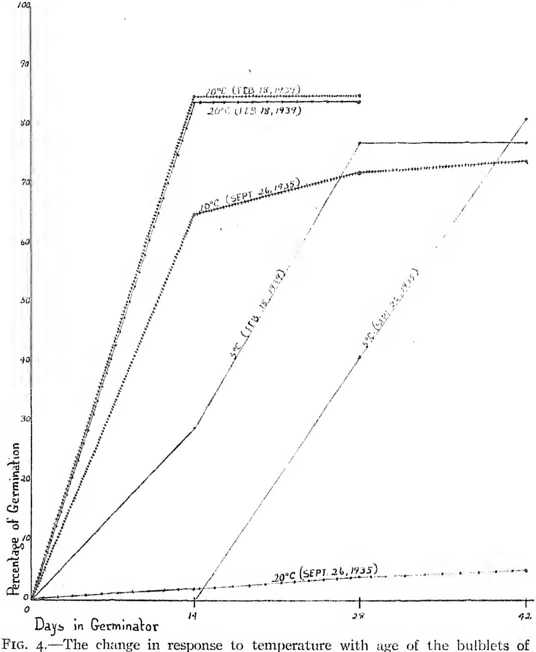

FIG. 4.—The change in response to temperature with age of the bulblets of *Poa bulbosa*. (Average of 2 samples.)

maximum germination as measured by a 28-day reading, but was not essential for maximum germination on old bulblets (detailed results not given).

EFFECT OF STORAGE AT VARIOUS TEMPERATURES ON LONGEVITY OF BULBLETS AND ON RESPONSE TO DIFFERENT GERMINATION TEMPERATURES

Sample 752695, 1933 crop from Oregon, was received August 11, 1933. The bulblets were placed in storage on the same day in sealed

containers at −10°, 2°, 10°, 20°, and 30° C and in a cloth bag at room temperature. The moisture content of the bulblets at time of storage was 12.90%.

The 49-day results on the bulblets held for 0, 3, 10, and 25 months' storage at −10°, 2°, and 10° C and at room temperature when germinated at 5°, 10°, and 20° C constant temperatures are given in Fig. 5. The bulblets stored at these four conditions showed no loss of viability during a storage period of 10 months. After 25 months' storage at 2° and 10°, the bulblets were of high viability. The bulblets at −10° and at room temperature storage germinated 45 to 65%. The low germination of the bulblets stored at room temperature appeared to be due to loss of life, but the low germination of the bulblets stored at −10° appeared to be due to a protracted dormancy, although loss of life may also have occurred. The results with the bulblets stored at 20° and at 30° C are not given in the graph. For some unexplained reason the bulblets fell in viability at a faster rate when stored at 20° than when stored at 30°. The germination of the bulblets stored at 20° was low (approximately 75%) after 3 months' storage and 0 after 10 months' storage. The bulblets stored at 30° did not lose in viability after 3 months' storage but fell considerably after 10 months' storage (germinated approximately 45%).

There was a marked effect of storage condition on germination response. Fresh bulblets and those stored for 3 and 10 months at −10° C required the use of potassium nitrate (Fig. 5) as well as a temperature of 5° for maximum germination. Bulblets stored at 2° and at 10° germinated equally well at 10° and 5° when potassium nitrate was used, but when water was used germination was better at 5° than at 10°. After 3 and 10 months' storage at room temperature, germination of viable bulblets was practically complete either with water or with potassium nitrate when germinated at 5° or 10°. Bulblets after-ripened in 10 months at room temperature so that they gave maximum germination with water at 20°. It might be of interest to point out that the bulblets stored at 30° and at room temperature showed an almost identical response to temperature of germination until the time of fall in viability of the 30° storage. In general, there was comparatively little gain in germination from 28 to 49 days at 10° and 20°. The greatest gain was shown at 5°.

SUMMARY AND CONCLUSIONS

A study was made of the effect of germination temperature, prechilling, and potassium nitrate on the germination of fresh and old bulblets of *Poa bulbosa*; and of the effect of storage temperature on after-ripening and on longevity of the bulblets.

Bulblets approximately 1 month old germinated better at 5° C than at 10° or 20° C constant temperatures, and better with potassium nitrate than with water.

Bulblets approximately 4 months old also germinated better at 5° C than at 10° or 20° C. Germination at a temperature alternation of 5° to 15° was faster than at a constant temperature of 5°, but complete germination of the viable bulblets was obtained only by pre-

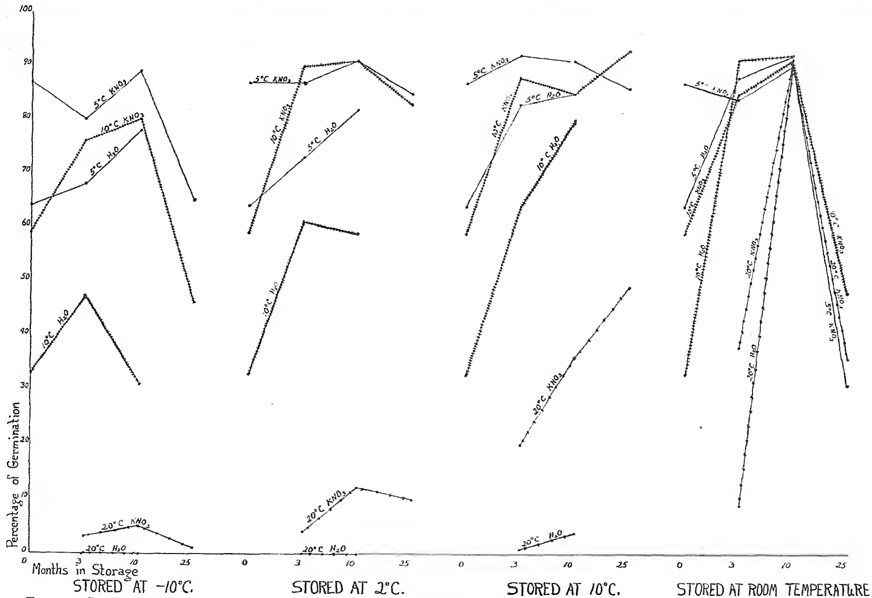

FIG. 5.—Germination in 49 days at 5°, 10°, and 20° C constant temperatures with the use of potassium nitrate and of water of bulblets of *Poa bulbosa* held in storage at indicated temperatures for 0, 3, 10, and 25 months.

chilling the bulblets at 5° for 7 or 14 days followed by germination at 10°.

As bulblets aged they were tolerant of higher germination temperatures. Bulblets approximately 2 years and 4 years old germinated faster at 20° C than at lower temperatures, but final germination was comparable at 10°. The 2-year-old bulblets required 49 days for completion of germination at 5°.

Bulblets having a moisture content of approximately 13% stored in sealed containers at 30°, 20°, 10°, 2°, and −10° C and in unsealed storage at room temperature showed a difference in longevity and in response to the germination temperature. When stored at room temperature, the bulblets after-ripened so that after 10 months' storage they germinated equally well at 5°, 10°, and 20°, but they had fallen in viability after 25 months' storage. Bulblets stored at 10° or at 2° showed no appreciable loss of viability in 25 months and maximum germination was obtained at 5° and at 10° but not at 20°. Bulblets stored at −10° became more resistant to the germination conditions tried so that maximum germination was not obtained.

BOOK REVIEWS

PLANT GROWTH SUBSTANCES

By Hugh Nicol. Brooklyn: Chemical Publishing Company, Inc. Ed. 2. XII + 148 pages, illus. 1941. $2.00.

THE author of this revised edition will be known to scientists as corresponding editor of *Chronica Botanica* and as former bacteriologist at Rothamsted and to the layman as author of "Microbes by the Million". Whereas the first edition, published in 1938, was of interest mainly to the chemist, this present edition contains considerable material of interest to the physiologist and horticulturist as well. In fact, the new material added deals largely with treatment of cuttings and seeds and the use of the various substances in grafting and flower inhibition and retardation.

The book contains 14 chapters, ranging from some practical phases interesting to the layman through methods of use, sources, and applications, to questions of structure and synthesis. Although a comparatively new subject, one is surprised at the extensive literature, references to which are given at the end of each chapter; and this is not the least of the valuable features of the book. Strangely enough no mention is made in the book of the practical use in this country of some of these synthetics to retard fruit abscission, which has attracted considerable attention during the past two years.

Anyone interested in this very intriguing subject will find this little volume helpful in bringing together something of the practical and technical phases as well as the literature of plant growth substances.

(R. C. C.)

THE SOILS THAT SUPPORT US

By Charles E. Kellogg. New York: The Macmillan Company. XI + 370 pages, illus. 1941. $3.50.

THE author of this book, who is well known to soil workers as Soil Scientist and Chief of the Division of Soil Survey of the U. S. Dept. of Agriculture, has departed somewhat radically from the orthodox text book on soils. The volume is aimed at a popular and descriptive account of soil origin, soil characteristics, and soil use. Publicizing the subject of soil conservation during the past few years has given the whole subject of soils an interesting popular appeal. This present volume is aimed at the general reader and student who want to know more about soils in their larger and broader aspects without all the more technical details usually given in an advanced text book on the subject. In a few words the book is as the author says, "one about soil and how soil and people get on together".

The main part of the volume is made up of 18 parts dealing with such subjects as the materials of soils; the life of the soil; soils of grassland, desert, and forest; use of soil for crops, preparation, fertilization, moisture; and soil and civilization. An appendix presents matters of soil classification, maps, groups, etc. The book is printed in large clear type and has a good index.

Its style, almost story-like in places but always accurate and sound in statement, should appeal to the popular reader as well as the student of soils. (R. C. C.)

AGRONOMIC AFFAIRS

NEWS ITEMS

Dr. H. K. Hayes, Chief of the Division of Agronomy and Plant Genetics, University of Minnesota, is spending six months at Santiago, Chile, where he is advisor to a group of government plant breeders as a part of the work of the committee to develop inter-American artistic and intellectual relations with South American republics. Dr. Hayes plans to return to Minnesota January 16, 1942.

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Dr. W. Ralph Singleton, Associate Geneticist, Connecticut Agricultural Experiment Station, is on temporary leave to serve as visiting professor of plant breeding and genetics at the University of Minnesota. Dr. Singleton will return to Connecticut about January 1.

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The Division of Agronomy and Plant Genetics, University of Minnesota recently moved into its new building which provides space for research laboratories, classrooms, and offices of the staff. A new greenhouse is also connected with the new building.

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Among those in residence at the University of Minnesota doing graduate work in agronomy and plant genetics are George Rogler, Mandan, N. D.; Rhea Stitt, Statesville, N. C.; T. R. Richmond, College Station, Texas; Eric D. Putt, Saskatoon, Sask., Canada; J. L. Bolton, Swift Current, Sask., Canada; Feeroze Husain, Burhanpur, India; and Yien Si Tsiang, Shanghai, China.

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George J. Callister of Beamsville, Ontario, Canada, has been appointed General Secretary of the Canadian Society of Technical Agriculturists for the duration of the war with headquarters in the Confederation Building in Ottawa. Mr. Callister entered upon his new duties on November 1.

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Biological Abstracts announces the establishment of a new section on animal production and veterinary science, beginning January, 1942. The new section will consist of ten abstract issues per year at an annual subscription rate of $5. Subscribers will also receive the index to the complete edition of Biological Abstracts.

JOE B. KELLY has been appointed as Assistant Research Agronomist at the Vermont Agricultural Experiment Station. Mr. Kelly received his B.S. degree at Mississippi State College in 1940 and his M.S. degree at Iowa State College in 1941.

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DOCTOR DEAN A. ANDERSON, former instructor in soils at Weber College, Ogden, Utah, has been appointed Assistant Professor of Agronomy at Brigham Young University, Provo, Utah. Doctor Anderson received his Ph.D. degree from the Agronomy Department at Iowa State College in 1932.

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THE AGRICULTURAL SCIENTIST AND THE WAR[1]

L. E. KIRK[2]

FIRST of all I should like to thank the members of the American Society of Agronomy for the honour conferred upon me when they elected me as President of the Society. I take it as a personal compliment, but more significantly as a generous gesture of friendship to my colleagues and yours who are citizens of Canada. Your action in electing a Canadian as President was doubly appreciated and assumed added significance in the light of Canada's entry into the war. Now that we have seen two full years of the conflict, and because of your vital concern with its progress, I thought you might be interested in a discussion of the position of the agricultural scientist in Canada in relation to the war effort that Canada is making. In this I have had in mind his contribution at the present time and that which he may be called upon to make in view of the war and the needs of agriculture in the post-war period.

One of the results of the present world conflict has been to focus sharply the attention of all thinking people upon the paramount importance of scientific training. It is literally true that the winning of the war depends on the contributions which the scientific workers are capable of making as the struggle progresses. Whereas in World War I the students in science departments at our universities enlisted almost in a body when hostilities began, in World War II they are being encouraged to attend university, engage in military training, and complete their studies. In Canadian universities military training for all male students is compulsory, and it is now possible to proceed to a degree and at the same time qualify for a commission in the armed forces. Virtually all students in category A have enrolled in the Canadian Officers' Training Corps. The universities have thus become an integral part of the organization for prosecuting the war. It is a clear recognition on the part of the government that highly trained personnel will be required in ever-increasing numbers if the war is to be brought to a successful conclusion.

Scientists are essential in three different fields of activity and in the following order: First, to man the research departments; second, to

[1]Address of the President delivered before the thirty-fourth annual meeting of the Society in Washington, D. C., November 13, 1941.

[2]Dean of Agriculture, University of Saskatchewan, Saskatoon, Sask., Canada.

make the results of research effective in mass production; and finally, to operate the highly intricate instruments of war in the actual field of combat. Trained personnel is essential in all three; as much in one as in another. It would be folly to discount the demands of what promises to be a long war and therefore the need of ever-increasing numbers of scientifically trained men.

Of the various professional groups the engineers have been in greatest demand. This was inevitable in a war of machines and highly mechanized armies. Mechanical engineers, electrical engineers, civil engineers, and chemical engineers, all are essential in various capacities. Equally indispensible, especially in research departments, are the students of pure science, as well as those of applied science. The personnel of the National Research Council of Canada has quadrupled in two years. The problems which must be solved are numerous, intricate, and often of the most vital nature. They extend to every operation of the army, navy, and air force, not to mention matters of concern to the civilian population. This vast and urgent department of the war effort leaves little room for precedence as between pure scientists and applied scientists, between chemists, physicists, and biologists, or between research specialists and technicians. Even specialists in language, law, and medicine, as well as many other fields of knowledge, may be found working with scientists on some military problem for which a solution must be found and found quickly.

One conspicuous result of all this teamwork has been a new appreciation of the other fellow's contribution and a realization of the enormous variety of types of training, talents, and skills which together are necessary for the prosecution of a modern war. Nor is it to be expected that the implications of what has been learned in wartime will be lost sight of in the post-war period. On the contrary, they are likely to exert a profound influence upon our thinking and practice in every phase of education. A new appreciation may be expected not only of the vital need of adequate educational facilities for young people but also of the need for making such facilities available to a much larger number. Greater flexibility in educational processes is clearly desirable so as to provide for the variety in types of training which seems to be indicated. And the importance of a sound basic training in science for all students in applied fields cannot be overemphasized. That which has been found so essential in war will be found even more essential in peace.

What is the position of the agricultural scientist with respect to the war effort? In Canada, during the past two years that we have been at war, they have found themselves for the most part in much the same position as the farmers, required to carry on without any appreciable departure from their normal peace-time operations. Like the farmers they have felt keenly the lack of a clean-cut objective which would identify their work with a specific function in the war effort, and like the farmers they have chafed a little under the necessity of carrying on without such a mandate. In this respect the demands of the present conflict have followed closely the pattern of the first two years of the first world war. There has been this differ-

ence, however, that whereas in the first world war technically trained men, particularly engineers and mechanics, were encouraged to join the active service force at once, in the present world war they are being rapidly absorbed into research departments and into industry pending the day when their services may be required to operate the instruments of war at the front.

Under these circumstances the demand for men trained primarily in biology and agriculture has been less keen than for men trained in engineering, physics, and chemistry; and as previously stated, some of the former have been restive. While many agriculturally trained men have found places of great usefulness and some have been given positions of extraordinary responsibility in industry, there have been many cases where men with bachelor's, master's, or Ph.D. degrees have been told to possess their souls in patience as their services were not yet required.

These observations reflect more or less the general situation, but as a matter of fact technical men in agricultural positions have found themselves fully occupied. The essential services have had to be maintained and expanded in certain directions. Compulsory rail grading of hogs, for example, was introduced in order to insure that the vastly augmented flow of bacon to Great Britain should not result in any lowering of quality standards. Seed production of many crops had to be promoted, notably field root and garden vegetables, fiber flax, and the newer varieties of rust-resistant wheat. Rehabilitation and conservation work has not been allowed to suffer, and soil surveys, especially in pioneer areas, has been speeded up. In other words, it was recognized from the first that agriculture would eventually play an important part in the war effort, even though in the first 18 months the supply of food was not a matter of special concern.

Yet almost as soon as war was declared, agricultural scientists were called upon to help solve some knotty research problems. The result has been some notable contributions of which a few examples may be mentioned.

Transportation of large quantities of bacon to Great Britain presented a serious difficulty because of the lack of ships equipped to handle perishable products. This problem was solved by a brilliant piece of research which made it possible to transport cargoes of bacon in ordinary vessels and at surprisingly low cost. The unique equipment whereby this is accomplished maintains a low temperature field in the hold of the ship at a level entirely satisfactory for the safe delivery of the product.

Another problem which presented great difficulties for the Canadian farmer was the finding of markets for certain products, notably apples, for which export demand had suddenly disappeared. In the case of apples, loss of established markets was the more serious because it was not possible to substitute other lines of production. The problem of marketing fresh fruit has been aided by the research work of agricultural scientists who were able to develop new methods of processing. The new products thus produced have had a large measure of success in the domestic market and some of them are in

demand for export to Britain, with the result that practically the entire surplus has been absorbed into consumption.

A new method was developed for the manufacture of high-grade canned apple sauce. Last year, approximately 3 million pounds was made by this process, utilizing certain varieties of apples that it was found difficult to dispose of through other channels. In the canned apple juice industry the development of the flash-heating sterilizing process and improvements in the tin can have been responsible to a large extent for a phenominal increase in the use of that product. Great progress has been made also since the war began in the technic of dehydrating and packaging of apples. Not only is the new product finding ready acceptance on the domestic market, but Great Britain has recently placed large orders, and to meet these demands a new type of dehydrator is being employed.

Improvements in the technic of vegetable drying has so raised the quality of these products that they now approach very closely to the fresh material. Cessation of exports of dried herbs and flavorings from Europe has stimulated the production and processing of these in Canada; the same is true of liqueurs, cordials, glaced cherries, and other products which were formerly imported.

Questions of adequate nutrition for the army and civilian population have greatly stimulated research in dietary matters. In this there has been some fine cooperation between medical men, agronomists, and cereal chemists. Special attention has been given to an adequate and balanced vitamin content in bread, the main objective being a white loaf sufficiently high in vitamin B complex to merit the whole-hearted support of the medical profession. Dr. L. H. Newman, Dominion Cerealist, is presenting a paper on the subject at this convention and no doubt will give a detailed account of what has been accomplished.

Research work along the various lines referred to above, to mention only a few, has of course not been confined to Canada. American scientists also have been working on the same problems and have made important contributions. The point to be emphasized is this, that war speeds up research, not only in war industries, but in every department of life. A modern war is necessarily a total war, so that matters of food production and problems of nutrition, for example, are as much a concern of defensive and offensive warfare as the building of ships and aircraft. Hence, in certain fields, technical agriculturists are as necessary to the war effort as engineers. It is not a question of guns *or* butter; it is really a matter of guns *and* butter.

It is interesting to note the similarity between the present war and the last war with respect to the position of agriculture. During the first two years in both wars the food supply was not a matter of national concern. But toward the end of the second year the importance of adequate food resources was generally recognized. We have already arrived at that stage in the present conflict, a situation with which our people are trying to cope and your people are preparing to meet. Unlike the last war there is no serious shortage of wheat, but the need for greater exportable quantities of meats, dairy products, eggs, and prepared fruits and vegetables is all too evident. In the

production, processing, and marketing of the required products, agricultural scientists will be called upon to play an important part. Research must be speeded up, new methods must be developed, and essential services to agriculture must be expanded. Specialists in biology and agriculture who have sought in vain for an active part in war industry are likely henceforth to find full scope for their energies in occupations for which they were specially trained. Nor is this work in any sense divorced from the war effort.

The inevitable lag which has characterized the participation of agriculture in the war effort has placed agricultural scientists somewhat in the position of a reserve. Fortunately, there are reserves also of chemists, physicists, engineers, and men with other types of training who are still engaged in less essential occupations. This reserve of scientifically trained men is very important. Problems raised by the war are numerous, unforeseen, and come along in a steady procession. The early stages of the war saw a feverish haste to build up strong research departments and primary war industries, making heavy demands on scientists, especially engineers, physicists, and chemists. But new problems are constantly being presented for solution and new types of industrial development will be required. For these purposes, as also for the active service forces, a reserve of technically trained men is essential. Agriculturists by virtue of their training in science, constitute an important element in this reserve and very soon all will be called upon to do their part.

It is abundantly clear that men trained in the basic sciences, and also in the mechanical skills, are a source of strength in times of national emergency. Graduates in agriculture, although specialized along many lines, all receive a basic discipline in science. Because of their knowledge of chemistry we see soil scientists being placed in charge of industries where explosives are manufactured and men trained in biology have been found very apt in developing certain types of delicate instruments and mechanical devices. Agricultural chemistry is a particularly useful specialization, as is also agricultural engineering. The point to be emphasized from these observations is that a sound training in the basic sciences not only makes an agricultural graduate more proficient in his chosen field of applied science, but it also makes him a more versatile, and therefore a more useful citizen, in war as well as in peace.

Occasionally we hear discussions and pronouncements on the *new order* which is to emerge after the war; sometimes it is the question of post-war reconstruction. In the present stage of hostilities these are problems fraught with obscurity and difficulty. There is little doubt, however, that there will be a new order, and that the post-war period will be one of reconstruction and rehabilitation. Questions of agricultural production, marketing, nutrition, food distribution, resettlement, and social planning will attain a prominence greater than at any previous time, with the result that agricultural scientists will have an unprecedented opportunity in helping to shape the future of society. The nineteenth century saw the rise and dominance of industry, the twentieth century will reveal the great significance of agriculture to the national welfare.

In this post-war world which lies ahead the agricultural scientists face a supreme challenge. They must accept their share of responsibility for the shape of things to come. By virtue of training and experience technical agriculturists are probably more cognizant of the basic facts of human society than any other group of individuals. They think in terms of natural phenomena and perforce must always maintain a very practical outlook on social problems.

Fortunately, the tradition of agricultural scientists is one of service and cooperation. They have never organized on the basis of narrow self-interest nor have their efforts been stultified by professional jealousy. As a group they have worked consistently for the greatest good of the greatest number without thought of personal agrandisement. Many fine examples of cooperative research could be recorded, a notable example being the team-work which resulted in the triumph of hybrid corn varieties. Furthermore, this same spirit has been just as conspicuous in the international field. The boundary line between the United States and Canada for example, has been no deterrent to the free exchange of scientific information and materials. Here also the best tradition of science has been observed, thus providing an example of the ideal situation where free intercourse and free trade exists between nations.

This fine tradition of international and intranational cooperation between technical agriculturists is a product of the scientific spirit. It stands as an example and symbol of a healthy relationship in human society. For this reason it has intrinsic value as a contribution toward social betterment. It also has great practical value in the solution of agricultural problems. While there is ample evidence that the day of the pioneer in science is still with us, it is abundantly evident that uninterrupted progress, especially in the solution of biological problems, is becoming more and more dependent on organized systematic research. In fact, the problems in agriculture are few indeed which do not require the combined efforts of specialists in several fields of knowledge for their satisfactory solution. Hence the enormous growth in our generation of institutions for research which are state-supported.

Problems affecting agriculture undoubtedly are destined to become more complicated and difficult to deal with. Thus far it is mainly the elementary questions that we have been asking. The more fundamental aspects of many of these questions still remain to be answered. Besides, research has become the indispensible ally of industry, and industry is rapidly invading the field of agriculture. In order to compete in the fierce struggle of economic forces, agriculture must look to the scientists for new technological developments which they alone can supply. The mechanization of agriculture has completely altered the outlook and conditions of rural life, and this revolution is so recent and far reaching that its implications are yet only partially understood or appreciated. Whatever the implications prove to be, it is certain that they will be accentuated and profoundly influenced by the world conflict which is now in progress; all of which emphasize the complexity of the problems which technical agriculturists may be expected to encounter in the not distant future. It also em-

phasizes the need for studies in rural sociology and suggests the paramount importance of wise leadership in all that makes for a happy and healthy rural community life.

What has been said with regard to the advantages of cooperative effort in research and the importance of sound leadership suggests the need of viewing agriculture as a whole and each agricultural problem as a part of the whole. The importance of relating the "particular" to the "general" becomes more imperative with the rapidly accelerating pace of research and with the magnitude of the potential changes which may be brought about as a result of the social and economic conditions growing out of the present world war. We must guard against the dangers of over-specialization, a tendency which seems to be inherent in our professional system. Knowledge has become highly departmentalized and research has suffered from too much fragmentation. The time has come for more attention to synthesis and coordination of effort. The organization of research on the basis of comprehensive projects closely related to the main direction of agricultural needs and trends should be a helpful method of conserving the resources of research workers and of guaranteeing that the fruits of research shall contribute directly to human welfare, which in the last analysis should be the main objective of applied science.

But how to determine the probable direction of agricultural progress in the future is precisely the crux of the dilemma. A problem that is clearly defined is already half way towards solution. To see the target clearly is the first requisite to straight shooting. Herein lies an opportunity which is not being fully utilized, or shall we say a responsibility which is not being fully realized. The agricultural scientist should use this opportunity to bring his knowledge and imagination to bear on the difficult but very important questions which arise in relation to the future welfare of the farmer.

The would-be promoters of agricultural betterment are numerous and vocal. Generally speaking they are most conspicuous among those who are least qualified to express an opinion on the subject. Many councils have resulted in much confusion of thought and a pathetic lack of understanding not only of the position of agriculture at the present time but of the nature of the problems which are likely to confront the farming population in the years to come. Who is better qualified than the agricultural scientist, especially men trained in soil science and agronomy, to influence the direction of agricultural research? Who has a better basis for constructive thought on matters agricultural than those who know intimately the processes of nature? I do not wish to imply that our research program has not been based on constructive thought nor do I desire to minimize the remarkable progress which has been made in nearly all departments of investigation in recent years, but I would suggest that there is a conspicuous need for a freer exchange of ideas with respect to future developments in agriculture. Such discussions might well be carried on through the medium of the JOURNAL of the American Society of Agronomy and the PROCEEDINGS of the Soil Science Society.

I am well aware that the tradition of scientists, especially in North

America, tends strongly to foster reticence in the matter of speculative writing; but if we are to understand agricultural problems in their proper perspective and if we are to try to evaluate the many factors which deserve consideration, it is a fair assumption that those who are given to constructive imaginative thinking in the field of agriculture would render a valuable service by committing their ideas to print.

SAGEBRUSH-GRASS RANGE SAMPLING STUDIES: VARIABILITY OF NATIVE VEGETATION AND SAMPLING ERROR[1]

Joseph F. Pechanec and George Stewart[2]

SAMPLING problems constantly confront individuals who are responsible for designing and conducting studies with native range vegetation. There is, however, a marked dearth of information specifically applicable to native range lands, that deals with the variability of native plant species, and with related factors affecting sampling and sampling error.

The nature and extent of variability in native vegetation have been studied by a few investigators. Davies (8)[3] found in Australia that natural pasturage was more variable than field crops. The total herbage yields had a standard deviation equal to 32.5% of the mean, and a slight but significant skewness to the left. Similar variations were found in Australia by Beruldsen and Morgan (2) who studied a sward of ryegrass, Kentucky bluegrass, cocksfoot, and clovers. Total herbage yields conformed closely to a normal distribution, but individual species distributions were badly skewed to the left. Blackman (3) and Ashby (1), working in England and on the continent, also found skewed frequency distributions for individual species in humid pastures.

Hanson (11), on the mixed prairie of western North Dakota, found variability in yields of total vegetation equal to 27.8% of the mean. Yields of individual species varied more than those of total vegetation and exhibited a pronounced skewness to the left. Costello and Klipple (6) reported the sampling errors for several native range types occurring in Wyoming and Colorado. Pechanec and Stewart (17) found frequency distributions distinctly skewed to the left and high variability associated with two plant species of the native sagebrush-grass range of southeastern Idaho.

The study herein reported was conducted during 1938 (a) to investigate the extent and nature of variation of native sagebrush-grass range species; (b) to examine on land of rough topography the efficiency and ease of subdivided random sampling,[4] using line plot sampling units; and (c) to secure some indication of the number of sampling units needed for sampling sagebrush-grass range areas.

Knowledge of variability in the production of range forage species and of the efficiency of subdivided random sampling derived from this study is applicable to range vegetation studies in which an at-

[1]Contribution from the Intermountain Forest and Range Experiment Station, U. S. Forest Service, Ogden, Utah. This study was conducted in cooperation with the Bureau of Animal Industry, U. S. Dept. of Agriculture at the U. S. Sheep Experiment Station, Dubois, Idaho. Received for publication May 12, 1941.

[2]Associate Forest Ecologist and Senior Forest Ecologist, respectively.

[3]Numbers in parenthesis refer to "Literature Cited", p. 1070.

[4]Subdivided random sampling (17, 5) may be defined as division of the area or population to be sampled into a number of parts so chosen that the species being studied varies less within each part than in the whole area. At least two sampling units, drawn at random, are to be secured from each part, or subdivision.

tempt is being made by means of replicated plots to reduce the error arising from natural variability. Reliability of conclusions would be greatly increased if preliminary sampling studies similar to the one here described were made before complicated surveys or experiments are established. It is likely also that the error in vegetation studies of cultivated pastures might be lessened by similar procedure.

EXPERIMENTAL PROCEDURE

The two phases of this study, (a) a uniformity trial and (b) an intensive random sampling of a 20-acre tract of native range, were conducted at the U. S. Sheep Experiment Station near Dubois, Idaho. Data on the extent and nature of variability in the production of native plant species were provided by the uniformity trial and augmented by those secured from the random sample of the 20-acre area. An examination of the ease of random sampling on uneven topography, using line-plot sampling units, data on the sampling error of more common range species, and a basis for estimating what might be an adequate sample for similar areas, were provided by the random sampling of the 20-acre area.

Before growth began in the spring of 1938, a uniform area of native sagebrush-grass range 100 by 160 feet was selected and subdivided into 640 plots, each 5 feet square. Dead herbage was removed to permit the harvest of current herbage. In June, when native range was approaching its maximum growth, grass and weed herbage on each 5 by 5 foot plot was clipped, segregated by plant species, placed in individual sacks, air-dried, and weighed. Weight of herbage production by shrubby species was estimated (15) because of difficulty in harvesting.

When half of the area was harvested, it was necessary to cease work except for two easily clipped species, arrowleaf balsamroot (*Balsamorhiza sagittata*) and tapertip hawksbeard (*Crepis acuminata*). Harvest of these two species was completed on the entire area. Data were thus secured for all species on 320 plots and for two species on 640 plots,[5] the latter of which were utilized by Pechanec and Stewart (17) in a previous study.

The random sampling study was conducted on a 20-acre area of native range, 1,320 by 660 feet in size, subdivided into 20 1-acre belts, 132 by 330 feet. In each of these belts, two line-plot sampling units, each composed of five subunits 100 square feet in area and 66 feet apart, were located at random, with the long axis of the sampling unit parallel to the long side of the belt. The sampling units covered 2.3% of the 20-acre area. Herbage production of each species was estimated on each subunit by the weight-estimate method (15) and recorded in grams of green weight.

In statistical analysis of the data methods presented by Fisher (9) and Snedecor (18) were used. To determine whether subdivision had produced an increase in precision, procedures outlined by Snedecor (18, Chapter 17) and Cochran (5) were followed. To calculate the gain in precision due to subdivision, it is necessary to secure an unbiased estimate of the variance of a sample located completely at random within the areas, subdivision being ignored. This latter estimate was secured by means of the formula:

$B + \frac{(M-1)\,N}{(MN-1)}\,\frac{A-B}{n}$ in which A = the mean square between subdivisions;

[5]Uniformity trial data are available upon request at the Intermountain Forest and Range Experiment Station, Ogden, Utah.

B = the mean square between line-plots within subdivisions; M = the number of subdivisions; N = the total number of sampling units within a subdivision; and n = the number of sampling units drawn from each subdivision.

INTERPRETATION OF DATA

VARIABILITY OF THE SAGEBRUSH-GRASS PLANT POPULATION

Typical semi-arid sagebrush-grass vegetation (7, 16) gives a false impression of uniformity in density and composition. Only a few species are visible at any one point and these few seem to be somewhat uniform in abundance. Approximately 220 plant species, however, are found in this type on the U. S. Sheep Experiment Station, and each species is highly variable in occurrence and production. Only sagebrush occurs on the entire area.

Twenty-one species differing widely in growth habit and character occurred in such abundance (Table 1) on the uniformity trial area

TABLE 1.—*Herbage yields, standard deviations, and coefficients of variability for plant species occurring on the 320 25-square-foot plots of the uniformity trial area.*

Species	Average dry weight per plot, grams	Standard deviation per plot, grams	Coefficient of variability, %
Thickspike wheatgrass (*Agropyron dasystachyum*)	6.78	9.30	137
Bluebunch wheatgrass (*Agropyron spicatum*)	62.54	20.14	32
Threadleaf sedge (*Carex filifolia*)	0.32	2.51	784
Junegrass (*Koeleria cristata*)	6.84	4.50	66
Indian ricegrass (*Oryzopsis hymenoides*)	0.67	3.52	525
Nevada bluegrass (*Poa nevadensis*)	4.54	3.88	85
Sandberg bluegrass (*Poa secunda*)	1.94	3.18	164
Needle-and-thread (*Stipa comata*)	2.30	5.79	252
Diverseleaf milkvetch (*Astragalus diversifolius*)	1.34	2.07	154
Astragalus (*Astragalus salinus*)	1.54	1.95	127
Arrowleaf balsamroot (*Balsamorhiza sagittata*)	71.87	43.71	61
Tapertip hawksbeard (*Crepis acuminata*)	5.81	6.29	108
Bastard toadflax (*Comandra pallida*)	0.19	0.67	353
Daisy (*Erigeron corymbosus*)	1.54	4.21	273
Wyeth eriogonum (*Eriogonum heracleoides*)	0.32	1.47	459
Tailcup lupine (*Lupinus caudatus*)	8.31	12.06	145
Pentstemon (*Pentstemon speciosus*)	1.34	2.30	172
Threetip sagebrush (*Artemisia tripartita*)	96.30	41.46	43
Rabbitbrush (*Chrysothamnus puberulus*)	13.32	13.75	103
Bitterbrush (*Purshia tridentata*)	1.83	8.42	460
Spineless horsebrush (*Tetradymia canescens inermis*)	10.43	13.62	131
All herbage	300.07	56.39	19
All forage	86.17	17.48	20

that their variability could be studied. An additional 29 species occurred infrequently. On the 20-acre area, 64 different species were found.

On the uniformity trial area variability of individual plant species is even greater than that noted in other studies (2, 8, 11), sagebrush having a variability of 43% of the mean yield (Table 1). Bluebunch wheatgrass, codominant species of the type and the most important forage species on the area, has a variability equal to 32% of the mean. Arrowleaf balsamroot, the chief weed species on this area as well as on many other sagebrush-grass areas, is twice as variable as bluebunch wheat grass. Other plant species, apparently insignificant individually but collectively important from a forage or ecologic standpoint, such as thickspike wheatgrass, junegrass, Nevada bluegrass, tapertip hawksbeard, pentstemon, and bitterbrush, have yield variabilities ranging from 66 to 460% of the mean. The variability of all herbage and all forage,[6] approximately 20% of the mean, is much less than that of the individual species.

Variability within the 1-acre belts is extremely high (Table 2). Except for the two most common species, bluebunch wheatgrass and threetip sagebrush, the variability of the yields of individual plant species exceeds 40% of the mean yield. The yields for weeds, grasses, and shrubs as groups vary less than any except the two most common species. Total forage yield varies less than the total herbage yield. This trend, similar to that found on the uniformity trial area, has also been reported for more extensive sagebrush-grass areas (14).

Direct comparison of the species variabilities derived from the 20-acre area with those secured from the uniformity trial to determine whether variability increases with increased area is difficult owing to differences in size and structure of the individual sampling unit and to the subdivided sampling method. But it was found that line-plot sampling units 400 square feet in aggregate area are from 0.4 to 0.6 as efficient per unit of area as the 25-square-foot unit (17). The 400-square-foot units are 16 times as large and yield 6.4 to 9.6 times as much information[7] per sampling unit as does an individual 25-square-foot plot. It might be assumed that the line-plot sampling units used in this study, 500 square feet in aggregate area, yield at least 8 times as much information as the 25-square-foot unit used in the uniformity trial. On this assumption, the variabilities of bluebunch wheatgrass, arrowleaf balsamroot, and threetip sagebrush, respectively, are approximately 5, 8, and 3 times as great within 1-acre belts of the 20-acre area as on the $\frac{3}{16}$-acre uniformity trial area.

Frequency distributions of plant species occurring on the uniformity-trial area are all skewed, with distributions of threetip sagebrush and bluebunch wheatgrass most closely approaching normal (Fig. 1).

[6]Herbage is used as meaning all current leaf and twig production, regardless of whether it is palatable to domestic stock. Forage is that portion of herbage palatable to livestock and obtained by multiplying herbage amounts for each species by the species palatability rating.

[7]"Information" as used here and in next several pages pertains to accuracy and reliability of data and conclusions. It is measured by "invariance", the reciprocal of variance. Data that "yield more information" reduce the magnitude of the errors involved.

Secondary species form distributions very strongly skewed to the left (Fig. 2), and the less abundant the species, generally the more skew the distribution, accentuated by the large number of plots upon which the species fails to occur.

TABLE 2.—*Herbage yields, standard deviations, and coefficients of variability for plant species occurring in the samples of the 20-acre area, standard deviation and coefficient of variability being calculated from variation within 1-acre subdivisions.*

Species	Average green weight per line-plot, grams	Standard deviation per line-plot, grams	Coefficient of variability, %
Thickspike wheatgrass	267.12	174.26	65
Bluebunch	1,456.12	309.95	21
Junegrass	85.12	34.16	40
Nevada bluegrass	72.38	42.68	59
Sandberg bluegrass	22.00	20.95	95
Needle-and-thread	125.75	82.83	66
Other grasses	171.89	—	—
All grasses	2,200.38	416.91	19
Diverseleaf milkvetch	34.00	25.45	75
Arrowleaf balsamroot	238.10	147.36	62
Tapertip hawksbeard	42.62	28.58	67
Daisy	178.88	80.55	45
Tailcup lupine	84.12	64.59	77
Pentstemon	12.62	17.77	141
Phlox (*Phlox stansburyii*)	25.62	19.80	77
Other weeds	262.76	—	—
All weeds	878.72	236.85	27
Threetip sagebrush	5,025.45	720.68	14
Rabbitbrush	725.12	474.70	65
Bitterbrush	1,063.55	651.19	61
Spineless horsebrush	448.12	244.59	55
Other shrubs	200.01	—	—
All shrubs	7,462.25	1,163.46	16
All herbage	10,541.35	1,446.64	14
All forage	2,124.50	389.21	18

The greater variability and accentuated skewness encountered in range studies as compared with those in cultivated agriculture may justify apprehension regarding suitable methods of statistical analysis. However, Eden and Yates (9), Hey (12), and Chapman (4) have shown the validity of Fisher's (10) "z" test when applied in the analysis of variance to data from distinctly non-normal distributions. This implies also the validity of the "t" and "F" tests. Validity of the analysis of variance with data from skewed distributions without transformation of the data presupposes that there are ample individuals in each treatment group and sufficient treatment groups. The greater the skewness of the data, the more important this becomes. Where

field data form strongly skewed distributions, increased sampling unit size and more efficient types of sampling unit have been found especially useful in reducing skewness (8, 13, 17). Thus, by a com-

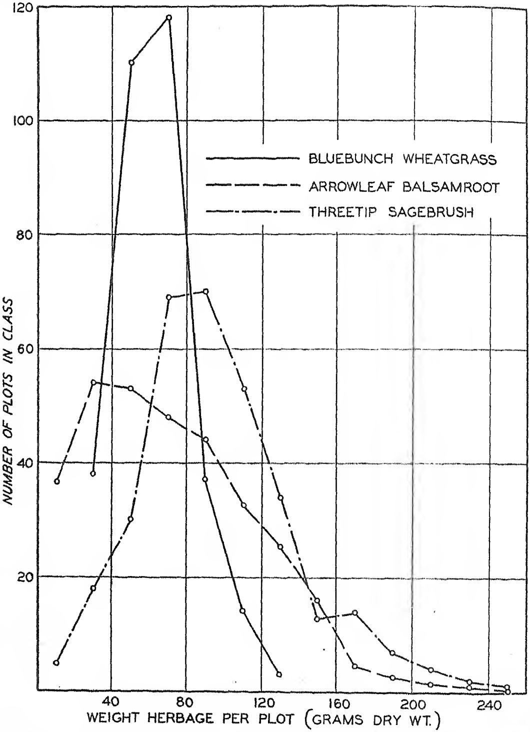

FIG. 1.—Distribution curves of herbage production by the three most abundant species occurring on uniformity trial area, with plots 25 square feet in area.

bination of efficient sampling unit size and shape and by adequate sampling, some of the dangers attendant on unequal variances and on relationships between group means and group variances may be partly avoided.

SAMPLING ERROR FOR SAGEBRUSH-GRASS RANGE SPECIES

Wide variability found within the 1-acre belts implies that a large number of sampling units will be required to secure sample means that give a reliable estimate of the population mean. On the 20-acre area, with the intensity of sampling used, only two species have sampling errors on a mean basis of less than 5% and only six species of less than 10% (Table 3). Thus, with two species the odds are 2 to 1

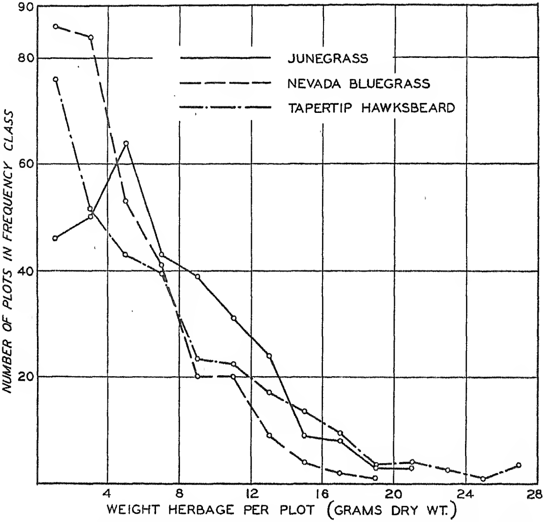

FIG. 2.—Distribution curves of herbage production by the three most important secondary species occurring on the uniformity trial area, with plots 25 square feet in area.

that the population mean lies within 5% of the sample mean, while six species have odds of 2 to 1 that the population mean lies within 10% of the sample mean. Some species have a sampling error of as high as 15 or 20%.

Two questions confront the investigator, namely, (a) What sampling error should be considered acceptable? (b) Which species or criteria of a plant community should be used to establish the intensity of sampling?

In sampling to an intensity that should provide a reliable estimate of the population mean, there is likely to be a wide variation in the

sample means secured from successive samples of a single area. The extent of this variation when 40 samples were actually drawn from the uniformity trial data of arrowleaf balsamroot (17), 20 for each of two intensities of sampling, may be examined in Table 4. From the total number of plot data available enough sampling units were taken at random to give an expected sampling error of 15.5% in one case and 7.3% in the other.

TABLE 3.—*Sampling error of plant species on the 20-acre area and size sample needed in sampling similar native sagebrush-grass range to fix fiducial limits at 5 and 10% from sample mean, 68% level of probability.*

Species	Sampling error of mean, %	Size of sample needed*	
		Limits, 5%	Limits, 10%
Thickspike wheatgrass	10	170	43
Bluebunch wheatgrass	3	18	5
Junegrass	6	64	16
Nevada bluegrass	9	139	35
Sandberg bluegrass	15	363	91
Needle-and-thread	10	174	43
Other grasses	—	—	—
All grasses	3	14	4
Diverseleaf milkvetch	12	224	56
Arrowleaf balsamroot	10	153	38
Tapertip hawksbeard	10	180	45
Daisy	7	81	20
Tailcup lupine	12	236	59
Pentstemon	22	793	199
Phlox (*Phlox stansburyii*)	12	239	60
Other weeds	—	—	—
All weeds	4	29	7
Threetip sagebrush	2	8	2
Rabbitbrush	10	171	43
Bitterbrush	10	150	37
Spineless horsebrush	9	119	30
Other shrubs	—	—	—
All shrubs	2	10	2
All herbage	2	8	2
All forage	3	13	3

*Number of line-plots 500 square feet in area composed of five 100-square-foot plots located 1 chain apart. Derived from column 2 of Table 2 by use of formula, $n = \frac{S^2}{(.05\bar{x})^2}$ or $\frac{S^2}{(.10\bar{x})^2}$.

When a sampling error of 7.3% was expected, one sample mean indicated the mean yield of the area to be 218.4 grams, or approximately 75% of the actual yield. With an expected sampling error of 15.5%, one sample mean was 140% of the actual mean and nearly twice as large as the lowest yielding sample. These variations are examples of what might be expected in the sampling of 20 uniform pasture study areas. Variation as wide as that shown in the group of

samples whose expected sampling error is 15.5% would be rather serious, especially in grazing experiments where the original stocking rates are based on vegetation inventories.

TABLE 4.—*Estimates of arrowleaf balsamroot yield obtained by 40 successive samples drawn from an area having an actual mean yield of 290.0 grams and a standard deviation of 89.7 grams.*

Means of 20 samples secured when expected sampling error was 7.3%*		Means of 20 samples secured when expected sampling error was 15.5%†	
252.7	292.7	247.0	*405.2*
264.0	289.3	250.6	305.4
299.4	263.2	*215.2*	282.9
307.5	281.7	270.9	274.4
273.2	*218.4*	232.1	272.9
252.5	275.0	247.1	305.1
294.2	300.5	279.6	230.8
296.3	289.7	277.1	236.9
281.5	287.8	240.6	342.0
310.6	265.2	271.8	259.2

*16 sampling units per sample.
† 4 sampling units per sample.

The effect of sampling error on experimental error and the resultant tests of significance should be carefully considered in setting up an acceptable degree of accuracy. In a replicated plot experiment where sampling is employed, any treatment mean will be liable to the error of sampling in addition to the experimental error.[8] Consider, then, the effect of sampling in a range experiment to a sampling error of 15%. Thus, if it is assumed that the experimental error in range studies is 15%, i.e., equal to the sampling error, the total error is approximately 21% ($1\sqrt{15^2 + 15^2}$). Now, since treatment mean differences ($\sqrt{21^2 + 21^2} = 30$) must exceed roughly twice their standard error, the experiment is such that differences of less than 60% between any two plots are likely to be considered nonsignificant. If more precise experimentation is desired, then not only must experimental design be improved but error must be reduced by efficient and intensive sampling.

Which species will serve as criteria of a plant community on which to base estimates of sampling intensity is a particularly perplexing problem. Although at least 50 plant species occupied the uniformity trial area, more than three-quarters of the total herbage production was contributed by three species, bluebunch wheatgrass, arrowleaf balsamroot, and threetip sagebrush. Two species, bluebunch wheatgrass and arrowleaf balsamroot, contributed two-thirds of the forage

[8]Experimental error is used as designating variations between plots treated alike that may be attributable to differences in site or plants occupying the site. Sampling error represents the variation between units used in sampling. Thus, when sampling is used, the total error is made up of two portions, one peculiar to the plot and the second attributable to accidents in sampling. Sampling error as used herein is the standard error of the mean expressed as a percentage of the mean.

produced on the area; no other single species contributing more than 7% of the forage production. On another similar range area it was found (14) that the same three species contributed two- thirds of the herbage and more than one-half the forage.

Since, in the study of reactions of native vegetation to experimental treatment or to climate, it is virtually impossible to sample adequately for a valid estimate of the reaction of all individual species, should the highly variable secondary species be ignored in deciding on intensity of sampling? Or, should sampling be only intense enough that total herbage production, total forage production, or production of the two or three more important species be measured within an allowable range of error?

This is a matter of judgment guided by the objectives of the experiment, but it should be kept clearly in mind in studies of plant succession that the discovery of valuable indicator species or even reliable indications of the trends of secondary species may be seriously impaired when measures of total vegetation or total forage are alone used to determine the intensity of sampling needed.

If changes of 50% in the abundance of secondary species are adjudged to be of significant magnitude, it will be necessary, allowing for an assumed experimental error of 15%, for the sampling error to be approximately 10%. Thus, the sampling error of the mean for total vegetation, of class totals, and of two major species might have to be about 5%, and for some of the most important secondary species about 10%.

With these criteria of judging adequacy of sampling, three sampling units located at random within each 1-acre subdivision would provide a sample of the 20-acre area such that the mean of the two major species, "all forage", "all herbage", "all grass", "all shrub", and "all weed" groups would have a sampling error of less than 5%, and 11 secondary plant species would have a sampling error of 10% or less. This intensity of samp'ing would seem to be fairly satisfactory for vegetation studies of sa͵ebrush-grass communities, but it is normally unattainable.

In the design of grazing experiments, however, and in selecting a satisfactory degree of accuracy to be attained in sampling, it must be remembered that it is often more expedient to invest the same amount of sampling effort over more replications of a single treatment than to increase the intensity of sampling for a single replication of pastures. Where variation between replications of a treatment is great, as compared to the sampling error, a reliable estimate of the treatment population mean can be achieved more efficiently by increasing treatment replication, using the same sampling percentage, than to increase the sampling intensity of the existent replications. With the choice of adequacy of sampling, as with the selection of size and shape of sampling unit, practical considerations such as the cost and labor involved in handling additional replications of treatments must be considered in judging the balance between sampling intensity and number of treatment replications. It is, therefore, impossible to establish a single sampling error suitable for all native range studies.

SUBDIVISION IN RANDOM SAMPLING

Subdivision as a method of improving the accuracy of random sampling has been found to yield appreciable increases in information (5, 13), and when tested on data from the uniformity trial area (17) appeared worthy of field trial.

When applied to the 20-acre area, the labor involved in randomization was no more than ordinarily encountered in systematically locating sampling units. It required only slight additional paper work in the office prior to locating the sampling units in the field.

Analyses of variance of herbage yield data for the three most important species occurring on the 20-acre area indicate that an increase in sampling accuracy was derived by subdivision (Table 5). Bluebunch wheatgrass, arrowleaf balsamroot, and threetip sagebrush each shows a large component of variation attributable to belts eliminated from the estimate of sampling error. Variance "between" ranges was from 2.3 to 3.9 times the variance "within" belts.

TABLE 5.—*Variance analysis using data from subdivided sampling of a 20-acre native sagebrush-grass range area, arbitrarily divided into two 10-acre areas.*

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Bluebunch Wheatgrass				
Between 10-acre areas	1	3,025,550	3,025,550	32.49*
Between 1-acre belts within areas	18	6,720,586	373,366	3.89*
Between units within belts	20	1,921,444	96,072	——
Total between sampling units	39	11,667,580	——	——
Arrowleaf Balsamroot				
Between 10-acre areas	1	152,276	152,276	7.01*
Between 1-acre belts within areas	18	915,290	50,849	2.34†
Between units within belts	20	434,234	21,712	——
Total between sampling units	39	1,501,800	——	——
Threetip Sagebrush				
Between 10-acre areas	1	19,182,250	19,182,250	36.93*
Between 1-acre belts within areas	18	31,592,394	1,755,133	3.38*
Between units within belts	20	10,387,480	519,374	——
Total between sampling units	39	61,162,124	——	——

*Exceeds 1% point of F.
†Exceeds 5% point of F.

Using the formula for variance per sampling unit, if subdivisions had been ignored, variance is estimated to be 220,868, 34,825, and 1,075,528, respectively, for bluebunch wheatgrass, arrowleaf balsamroot, and threetip sagebrush. Comparison of these estimated variances with those secured using 1-acre subdivisions indicates that where sampling units randomized within 10-acre blocks would have

yielded 1 unit of information, those randomized within 1-acre belts yielded 2.30, 1.60, and 2.07 units, respectively, for the three species.

When this inquiry was extended to the species listed in Table 3, the benefits of subdivision were found to vary widely with plant species. With Sandberg bluegrass, thickspike wheatgrass, and rabbitbrush, increases in information were so slight as to be adjudged nonsignificant. With daisy and bitterbrush, 8 times as much information was secured. Of the 17 species listed, only 5 species gave no evidence of benefit from subdivision. One of these species, Sandberg bluegrass, is known to be more or less uniformly distributed. The other four species may be uniformly distributed or merely by chance they may have failed to indicate increased precision from subdivision.

Even though subdivision on the basis of land office divisions may not yield increased information, it is not likely that it will decrease the information secured. With variable native range vegetation the information on some or all of the plant species may be greatly increased. In addition, it is often convenient to subdivide sampling because of ease in administration of field work.

Much more consistent increases in information might be secured if each subdivision was composed of a single vegetation subtype or soil type. To this, complexity of the problem of randomization within strata made up of irregularly conformed subtypes is a serious obstacle but one which, when the solution is formulated, will add appreciably to the accuracy of sampling.

APPLICATION OF RESULTS

Data regarding variability of native range species and factors influencing sampling error are directly applicable only in the immediate vicinity of the study area. On any new area, whether sagebrush-grass or other range type, preliminary investigations should point the way to the proper sampling-unit size, conformation, method of placement, and intensity of sampling, *before* intensive experimental studies are undertaken that will involve the problems of sampling. Such exploratory investigations will find a reservoir of information regarding cultivated fields upon which to draw. Application of principles so derived may not prove difficult.

Randomization of sampling units and subdivision of sampling are useful tools readily adaptable to range studies, but many ramifications of their application yet remain to be solved.

The intensity of sampling required to secure the desired high accuracy in range experiments seems unattainable, but it should stimulate additional search for methods by which less exorbitant intensities may be used to achieve the same accuracies. If an efficient and simple way can be devised for randomizing sampling units within vegetation types of irregular conformation, the sampling intensity necessary to conform to specified degree of accuracy may be substantially decreased. Planned use of covariance analysis appears to justify investigation. Sampling units, staked for the duration of the study to permit preliminary, intermediary, and/or final observations to be made on the same identical spots, may permit doubling

of experimental precision in tracing trends of forage production or plant density.[9] Or, if planned in the original sampling design, it may be found that one-half the number of sampling units are needed to achieve the desired degree of accuracy as would be needed if preliminary and final observations are each made on a separate series randomly located. Some alteration in sampling procedure may be necessary where methods of plant measurement, either complete or partial harvest, result in disturbance to vegetation of the sampling unit. In such cases, each sampling unit might be composed of a cluster of plots. Two plots, separated by an adequate border and to which time of observation would be assigned at random, would make up each cluster where only preliminary and final observations are to be made. Thus, the error in tracing trends in vegetation cover would be composed of variations in trends of similarly treated sampling units plus the variation between plots closely adjacent to each other. The large variation between plot clusters within subdivisions would be eliminated from the test. The merit of this proposal needs yet to be tested.

SUMMARY

Variability of native sagebrush-grass range species and factors influencing sampling error were studied on the U. S. Sheep Experiment Station range near Dubois, Idaho. Vegetation on a block of native range, $\frac{3}{16}$ acre in area, was harvested in 5 by 5 foot subdivisions. A 20-acre area was sampled by using line-plot sampling units located at random within 1-acre subdivisions.

The sagebrush-grass type, notwithstanding its aspect of uniformity, is a heterogeneous community composed of plant species highly variable in abundance. On the $\frac{3}{16}$-acre area 50 species were found, 26 of which were abundant enough to permit a study of their variability. Sixty-four species were found on the 20-acre area.

Variability in yield of individual species on 5 by 5 foot units, was greater than 30% of the mean, or 2 to 3 times that encountered in experiments on cultivated land. With some more important secondary species the variability exceeded the mean.

Within 1-acre subdivisions of the 20-acre area, the variabilities of bluebunch wheatgrass, arrowleaf balsamroot, and threetip sagebrush were approximately 5, 8, and 3 times as great, respectively, as on the $\frac{3}{16}$-acre area.

With the exception of threetip sagebrush and bluebunch wheatgrass, the frequency distributions of the native species were found to be characteristically strongly skewed to the left.

Random sampling with line-plot sampling units, within subdivisions, is as easily used in the field as systematic sampling and provides as dividend a representative estimate of the sampling error.

Subdivided random sampling in 1-acre belts increased the information secured 1.31, 0.61, and 1.08 units, respectively, for bluebunch wheatgrass, arrowleaf balsamroot, and treetip sagebrush.

[9]PECHANEC, JOSEPH F. Application of analysis of covariance to range research. Intermountain Forest and Range Experiment Station Technical Note No. 1. 1941.

The sampling intensity required to provide an adequate sample of a native range area varies greatly with the plant species being studied. Sampling intensity based on aggregate herbage yields of all species, on total forage of all species, or on the herbage production by the most important species was found seriously to underestimate the intensity required to sample secondary species. On the other hand, ignoring secondary species when determining needed sampling intensity may seriously limit usefulness of the data from the standpoint of studies of plant succession, indicator species, or poisonous plants.

To provide thoroughly reliable information for intensive research studies, sampling might have to be of sueh an intensity that the sampling error is 5% of the mean for major species and elass totals and 10% for secondary species. In experimental range studies it is likely to be more effective in reducing error to apply the same amount of sampling effort on several replications of the same treatment rather than to increase the intensity of sampling for a single replication.

For 20-acre areas of native sagebrush-grass range similar to that studied, 60 line-plot sampling units 500 square feet in aggregate area, randomized in 1-acre subdivisions are required to provide mean yields having errors as low as 5% for major species and 10% for secondary species.

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SULFUR AND NITROGEN DEFICIENCY RELATIONSHIPS IN SUGAR BEETS GROWN FOR SEED IN OREGON[1]

BION TOLMAN AND GOLDEN L. STOKER[2]

GROWING of sugar beet seed by the overwintering method (2)[3] has come into widespread use in the United States during the past 12 years. The development of sugar beet seed production by this method in Oregon, leading to the studies reported in this paper, has taken place in the past 5 years (10).

From results with the sugar beet seed crop in various areas it appears that soils of good tilth and more than average fertility are desirable for growing the crop. In addition to the use of manure, nitrogenous fertilizers applied as side-dressings to the growing crop are commonly used (3, 5). It has been shown that the nitrogen supply available to the plant during the fruiting period governs, to a large extent, the utilization by the plant of stored carbohydrate reserves in the sugar beet root. If nitrogen becomes a limiting factor during this period, utilization of carbohydrate root reserves stops and the maturing of the seed crop may be seriously interfered with (5).

In 1914, Reimer (6), in a preliminary report, called attention to serious sulfur deficiencies in soils in southern Oregon and, in 1919, with Tarter (7), gave a full account of the results from sulfur application. Since that date extensive work carried on by the Oregon Experiment Station has demonstrated the value of sulfur as a fertilizer on many crops in western Oregon (1, 4, 9).

The preliminary studies reported in this paper deal with both nitrogen and sulfur deficiencies in relation to sugar beet seed production, and the further relationship of sulfur deficiency to nitrogen utilization.

PLAN OF EXPERIMENT

The experimental plot was located near Jefferson, Oregon, on soil of the Newberg series. The plot included treatments of lime, boron, potash, phosphorus, sulfur, and nitrogen. Only the nitrogen and sulfur treatments are considered in this paper. The boron deficiency relationships have been reported (10), and no significant response to lime ($CaCO_3$), potash, or phosphorus was observed in this experiment. Further critical work is necessary, however to determine definitely the effect of these elements in sugar beet seed production in the Willamette Valley. The experimental design consisted of a split-plot arrangement (11). There were eight replicated plots of each treatment. Appropriate errors were obtainable for measuring the direct effect of both sulfur and nitrogen and also the interaction effects of these two elements.

The sulfur treatments constituted the main blocks and each sulfur block was of sufficient size to accommodate three nitrogen treatments. Ninety-four pounds

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[3]Figures in parenthesis refer to "Literature Cited", p. 1078.

of elemental sulfur were broadcast on the sulfur plots and worked into the soil during the final operations of seedbed preparation.

The nitrogen plots ran across both the no-sulfur and plus-sulfur blocks and consisted of strips six rows wide and 240 feet long. Nitrogen was applied as sodium nitrate.

The plot was planted on August 21, 1939, with a four-row beet drill equipped with a fertilizer attachment. One-hundred pounds of sodium nitrate were sown with the seed on two of the nitrogen plots in each set of three, but the third received no nitrogen at that time. The plots planted without nitrogen came up in 5 to 6 days, but in those where sodium nitrate was sown with the seed, germination was so delayed that a cyclone weeder was run over the entire field to prepare it for replanting. A heavy rain followed and by the time the soil was dry enough to replant the beets were up on the plots where nitrogen had been sown with the seed. The weeder had destroyed the plants on the no-nitrogen plots which had come up prior to the rain and so those plots were replanted on September 7. Thus there were two dates of planting. There was a difference of 8 to 10 days between the two plantings in actual germination and seedling emergence. In view of this fact, the planting date of the earlier planted plots is hereafter given as August 28, the date of sufficient rainfall to furnish the needed moisture for germination.

The three nitrogen treatments which formed the sub-plots on each no-sulfur and plus-sulfur block were as follows:

Treatment 1. No nitrogen with seed
- 318 pounds per acre of sodium nitrate side-dressed Oct. 15, 1939
- 330 pounds per acre of sodium nitrate side-dressed Apr. 6, 1940

Treatment 2. 100 pounds of sodium nitrate per acre at planting time
- 233 pounds of sodium nitrate per acre side-dressed Oct. 15, 1939
- 330 pounds of sodium nitrate per acre side-dressed Apr. 6, 1940

Treatment 3. 100 pounds of sodium nitrate per acre at planting time
- No further applications of nitrogen

It is to be noted that treatments 1 and 2 were very similar as to nitrogen applied, but treatment 1 was cultivated out and replanted September 7, introducing a differential in emergence date, and there was also a slight difference in time of nitrogen application. It is felt, however, that difference in seedling emergence date is the principal difference between treatments 1 and 2.

Irrigation was applied during the summer as needed by an overhead irrigation system.

The four center rows of each plot were harvested July 23, 1940, for yield data, the outside rows being discarded as buffer rows.

Climatic and soil conditions under which these tests were conducted have previously been reported (10).

RESULTS AND DISCUSSION

EFFECTS ON PLANT GROWTH AND DEVELOPMENT

The first effects of the sulfur and nitrogen treatments, aside from the effects on germination already noted, became visible during the last of September when the beets in general were beginning to show need for moisture. During this period, beets on the sulfur blocks were noticeably greener than where sulfur had not been applied. Side-dressings of nitrogen were made on treatments 1 and 2 on

October 15, 1939, and about 2 weeks later there was a noticeable response as evidenced by increased size, green color, and waxy appearance of the leaves. During the early part of November the No. 3 treatments, which had received only the 100 pounds of sodium nitrate at planting time, turned distinctly yellow in color in contrast to the more vigorous growth of beets on plots to which side-dressings of sodium nitrate were made on October 15, 1939. There was very little change in this general picture during the winter months.

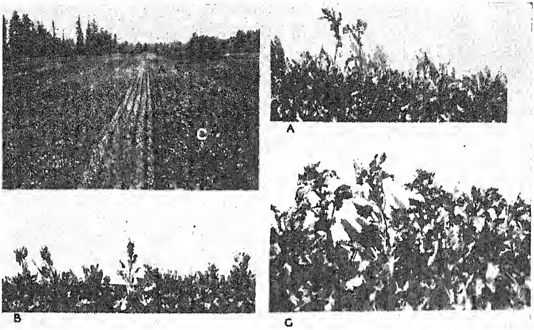

FIG. 1.—General view of experimental plot near Jefferson, Oregon, showing nitrogen-deficient strips and sulfur-deficient blocks, also the location where the three detail pictures, A, B, and C, were taken. A, no sulfur, 333 pounds of $NaNO_3$ in the fall and 330 pounds in April, 1940. B, 94 pounds of sulfur and 100 pounds of $NaNO_3$ applied in the fall. No spring treatment. C, 94 pounds of sulfur and 333 pounds of $NaNO_3$ in the fall plus 330 pounds in April, 1940. (Photographs by F. V. Owen, Geneticist, Division of Sugar Plant Investigations, Bureau of Plant Industry, U. S. Dept. of Agriculture, May 6, 1940.)

As growth was resumed in the spring the nitrogen and sulfur differences became more pronounced and it became evident by early May, during the period of rapid seedstalk development, that the response to nitrogen was very limited in the absence of sulfur. This relationship was manifested by both lack of growth and also by a marked yellowing of the foliage (Fig. 1).

Accompanying the yellowing of the foliage was also a breakdown of the leaf tissue (Fig. 2). During this same period extensive leaf spot injury was also noted on the leaves. The fungus associated with this leaf spot was later identified by G. H. Coons[4] as *Ramularia beticola* Fautr. and Lamb. The leaf spot was much more in evidence on the sulfur-deficient plots.

By June 14, 1940, it was possible to walk into the plots and deter-

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mine the boundary of the sulfur-deficient plots by the amount of dead leaves evident on the seedstalks of the beets. There was also another striking development in the deficiency symptoms at this time. Many of the plants in the sulfur-deficient plots had developed a trotzer-like vegetative growth instead of flowering normally as had the beets in the plots to which sulfur had been applied. At harvest time the sulfur-deficient blocks were evident by the vegetative condition of many of the seed heads and the lack of matured seed as

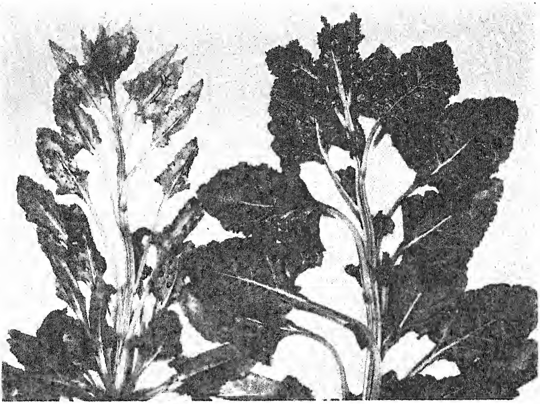

FIG. 2.—Sulfur-deficiency symptoms as manifest by breakdown of leaf tissue, yellow color, and restricted growth is shown on left. Some leaf spot caused by the fungus *Ramularia beticola* Fautr. and Lamb, is also evident on the sulfur-deficient leaves. Height difference of seedstalks of plants from the no-sulfur and sulfur plots is not shown in the above figure. The entire seedstalk of the sulfur-deficient plant is shown, but the picture includes only the top two-thirds of the seedstalk of the normal plant.

contrasted with the heavy set of seed on the plants which received both nitrogen and sulfur (Fig. 3). The vegetative terminal growth of the sulfur-deficient seedstalks also caused a marked contrast in color between the sulfur and no-sulfur plots. The plots to which sulfur had been applied had taken on a brownish cast from the color of the matured seed and sulfur-deficient plots were a yellowish green color. The differentiation of the sulfur treatments in the large block effects can be seen in Fig. 4.

SEED YIELDS

The yield data furnished striking confirmation of the visible growth effect of the nitrogen and sulfur relationship. Significant

differences in yield were obtained from both the nitrogen applications and the addition of sulfur (Table 1). It will be noted from the figures in the body of the table, however, that most of the increase

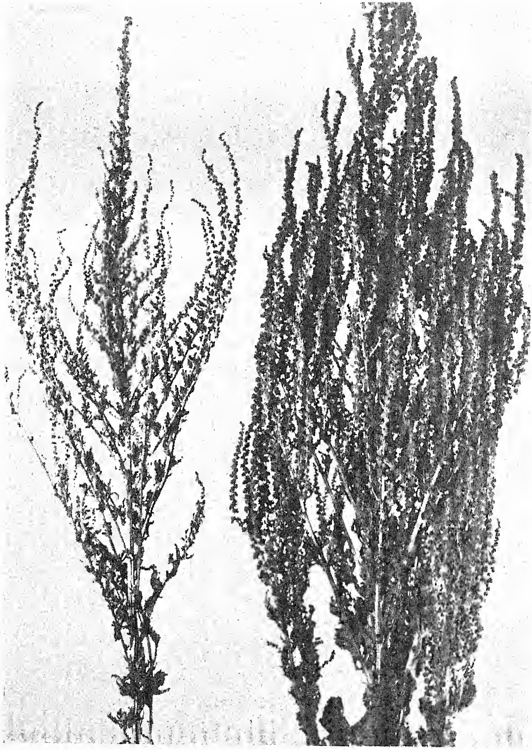

FIG. 3.—Contrast of seed development on a sulfur-deficient plant (left) with one grown on plot receiving 94 pounds of sulfur per acre. Not all the plants in the sulfur-deficient plots remained this vegetative, but a sufficient number developed this trotzer-like seedstalk to make a striking contrast with the plots receiving sulfur.

FIG. 4.—General view of experimental plot taken at harvest time July 23, 1940. One of the sulfur-deficient blocks is evident in the left foreground.

in yield as a result of the nitrogen treatment came in the presence of the sulfur application. It is also evident that all the response to sulfur came on the plots that received additional applications of nitrogen after planting. This is clearly pointed out further in the relationship of the mean squares listed in Table 2. The F value (8) for the nitrogen × sulfur interaction is greatly in excess of the 1% point level of significance.

TABLE 1.—*Pounds of clean seed per acre from replicated plot test in which three nitrogen treatments were used with and without addition of sulfur to the soil, Lamb experimental plot, Jefferson, Oregon, 1939–40.*

Treatment No.	Planting date	Nitrogen application	Subplot comparisons, lbs.		Average N treatments, lbs.
			No sulfur	94 lbs. sulfur, fall	
1	Sept. 7	318 lbs. $NaNO_3$ in fall+330 lbs. $NaNO_3$ in spring	1,310	1,672	1,491
2	Aug. 28	333 lbs. $NaNO_3$ in fall+330 lbs. $NaNO_3$ in spring	1,323	2,061	1,692
3	Aug. 28	100 lbs. $NaNO_3$ fall; no N in spring...	1,073	1,001	1,037
Average yield of sulfur plots			1,235	1,578	1,407

Diff. for signif. of six subplot comparisons, odds 19:1 =137 pounds.
Diff. for signif. of two sulfur treatment means, odds 19:1 =238 pounds.
Diff. for signif. of three nitrogen treatment means, odds 19:1 =165 pounds.

Similar analysis was made of the germination percentage, the weight per bushel, and the cleanout percentages of seed from each plot. None of the treatments significantly affected the quality of seed produced, using the above factors as an indication of quality.

The results indicate that applications of both nitrogen and sulfur will be necessary in commercial sugar beet seed production in western

Oregon. No specific recommendation as to maximum amounts that can be economically applied and other details of fertilizer practice can be made until results of further work being carried on by the Division of Sugar Plant Investigations, Bureau of Plant Industry, in cooperation with the Oregon Experiment Station and the West Coast Beet Seed Company become available. It was indicated, however, that the maximum of 106 pounds of nitrogen applied on the experimental plot was insufficient and that nitrogen applications may need to be in excess of 125 pounds of nitrogen per acre if maximum yields are to be obtained.

TABLE 2.—*Mean squares and F values for the yield in clean seed per acre of the nitrogen and sulfur plots and the interaction relationships.*

Variation due to	Degrees of freedom	Mean squares	Calculated F values	Significant F values	
				5%	1%
Between blocks.....	7	177,883	1.51	3.79	7.00
Sulfur vs. no sulfur..	1	1,406,990	11.93	5.59	12.25
Remainder (error A)	7	117,956	—	—	—
Nitrogen treatments	2	1,801,699	36.50	3.74	6.51
Remainder (error B)	14	49,354	—	—	—
Nitrogen × sulfur..	2	658,496	38.89	3.74	6.51
Remainder (error C)	14	16,932	—	—	—
Total...........	47	—	—	—	—

SUMMARY

Both nitrogen and sulfur deficiencies were strikingly evident on sugar beets grown for seed in the Willamette Valley in Oregon. Nitrogen deficiency was manifest by retarded, spindly growth, yellowish green color, and fewer plants entering into seed production. Sulfur deficiency was evident by retarded growth, yellow color, breakdown of leaf tissue, and increased susceptibility to *Ramularia* leaf spot. In addition to these symptoms, many of the plants developed a trotzer-like vegetative growth instead of flowering normally. There was a striking interaction response of sulfur and nitrogen, both on plant development and on seed production. Sulfur application did not affect seed production on plots where nitrogen was not applied. Also, the response to nitrogen was much greater in the presence of the sulfur treatment. Applications of both sulfur and nitrogen will be necessary in commercial sugar beet seed production in the Willamette Valley.

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MANGANESE DEFICIENCY OF OATS ON ALKALINE ORGANIC SOILS[1]

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FOR more than 30 years, "grey speck" disease of oats has been recognized as an indication of manganese deficiency in the soils of Europe and Australia. Sjollema and Hudvig (9),[3] in 1909, reported the occurrence of the disease in oats grown on certain alkaline moors in the Netherlands. According to their report, the disease could be eliminated by the application of acid canal sediment, of raw peat, or especially, of manganese sulfate.

This deficiency symptom is not known as grey speck in all regions. In Wales, it is known as "halo blight" (2); and in Germany and the Netherlands, as "dry spot" and "leaf speck" (7). These names are descriptive of certain stages of the development of grey speck disease, any one of which may predominate over the others under certain conditions, such as type of soil, climate, and variety of oats raised. Grey speck disease has not been recognized as such in the United States, although it has been known for some time in the Province of Ontario, Canada. Albert's (1) description of the manganese deficiency symptoms of oats is very characteristic of the dry spot stage of grey speck disease.

According to the literature, the manganese-deficient soils of the United States appear to be limited to the mineral soils along the Atlantic coastal plains, in certain regions in the Pacific Coast states, and to the alkaline organic soils of Michigan, Indiana, Ohio, New York, and Florida. The occurrence of the deficiency on mineral soils (6) is quite commonly associated with over-liming, while, with the organic soils, it is associated with over-liming, burning, alkaline spring water, or the presence of a marl bed near the surface of the soil (4).

The identification of grey speck disease in oats should be of considerable importance, because it would permit the linking of the research work on manganese-deficient soils of Europe and Australia with those of this country. It would thus furnish a reliable and widely recognized symptom by which manganese-deficient soils could be identified and the treatment of oats so afflicted made a relatively simple matter.

EXPERIMENTAL

For the purpose of making a study of grey speck occurrence and control on alkaline organic soil, a series of pot experiments were conducted under greenhouse conditions, using a well-decomposed soil

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[3]Figures in parenthesis refer to "Literature Cited", p. 1092.

having a pH of 7.4 to 7.8, except where otherwise noted.[4] Mineral fertilizers were applied in the form of a chemically pure 0–8–24 mixture at the rate of 500 pounds per acre for each oat crop. Chemically pure sodium nitrate was applied weekly, uniform in amount for each set of pots and at a rate sufficient for the prevention of nitrogen starvation.

DEVELOPMENT OF GREY SPECK

Since preliminary observations indicated that there might be some difference in the development of grey speck by different oat varieties, a greenhouse study on alkaline organic soil was carried out with four of the varieties commonly grown in Michigan. Table 1 presents the count of the lesions on the four varieties. All four varieties were very chlorotic. Wolverine oats proved to be one of the most susceptible to the disease and for that reason was selected as the variety used in the succeeding studies.

TABLE 1.—*A comparison of the development of grey speck disease on different oat varieties when grown on a manganese-deficient organic soil.*

Variety	Percentage of plants showing grey speck		Severity of disease
	50 days after seeding	60 days after seeding	
Wolverine	89	100	Severe
Iogold	76	100	Severe
Gopher	55	98	Severe
Huron	12	27	Mild

When Wolverine oats were grown on this alkaline organic soil, very low in active manganese but well fertilized with a chemically-pure 0–8–24 mixture, a physiological breakdown of the tissue occurred, characteristic of grey speck disease. As observed in this and later studies, this tissue breakdown on the Wolverine variety takes place as follows: A faintly greyish lesion, grey speck, develops generally about halfway along the leaf, gradually becoming more pronounced, until, in a few days, the upper part of the leaf breaks over at a sharp angle. This greyish shade gives way to a round or oval, bright yellow coloration with a reddish fringe developing at the outer edges of the lesion, thus producing a halo effect. Meanwhile the greyish shade of the lesion extends outward into fresh tissue. This stage may be followed by the death of all the tissue of the basal portion of the leaf, but the tip of the leaf may remain green for some time. Ultimately, however, the whole leaf dies. With hot, dry weather, however, the plant may send out new leaves and recover to the extent of producing some seed. The various stages of grey speck are shown in Fig. 1.

[4]The organic soil used in the greater part of this study was a well-decomposed muck containing about 70% organic matter. Grey speck has also been observed on alkaline soils of a more peaty nature.

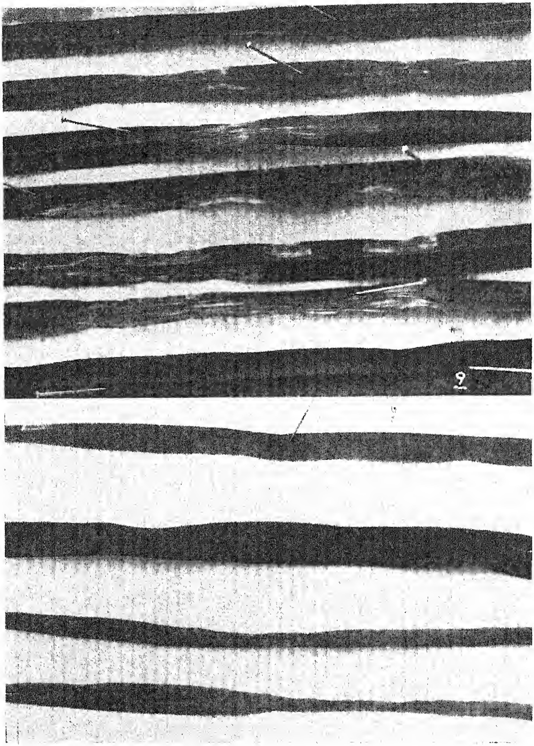

FIG. 1.—Grey speck disease on Wolverine oats grown on alkaline organic soil. *Upper picture:* top leaf, grey speck or primary stage in extreme upper left edge of leaf; second, third, and fourth leaves, various phases of the halo stage; fifth leaf, halo stage, approaching dry spot stage; sixth leaf, advanced or dry spot stage; bottom leaf, a normal healthy specimen produced by application of manganese sulfate. *Lower picture:* top leaf, grey speck, bordering on halo stage; second leaf, normal; two lower leaves, late stages of disease showing upper portions of leaves (left) still green. All affected leaves were somewhat chlorotic.

Like the Wolverine, the Iogold and Gopher varieties proved to be very susceptible to the tissue breakdown. In these two varieties,

however, the spots occur more or less as streaks. Huron, on the other hand, proved to be very resistant to the development of the spots, which, in its case, were very small and of a round or oval shape.

Seasonal and soil factors influence the amount of development and the progress of the various stages of the disease. A cool season favors the grey speck stage, while higher temperatures will cause the halo stage to predominate. In addition to its occurrence on alkaline organic soils, the authors have observed grey speck disease on oats on occasional high-lime Michigan mineral soils (Fig. 2). These instances

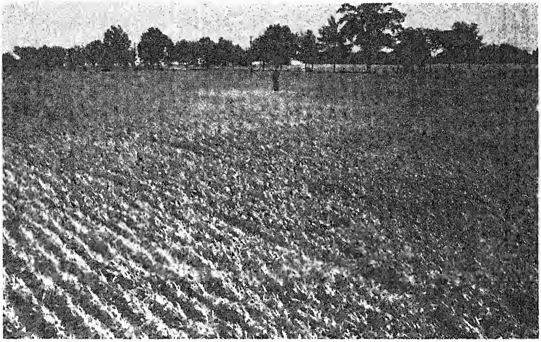

FIG. 2.—Field of Iogold oats afflicted with grey speck disease on a mineral soil which at one time had a shallow organic soil covering part of which had been destroyed by burning with the remainder becoming incorporated in the underlying mineral layer. The light areas of oats through the center of the picture on alkaline or nearly alkaline soil were badly affected but recovered to the extent of producing heads. This field is about 30 rods distant from the plots shown in Fig. 3.

have been almost entirely on marsh border soils or in field depressions which were at one time shallow organic soils underlain by sand. This is not an abnormal situation, since these high-lime black sandy soils, which were originally shallow mucks or peats, maintain a nutrient requirement more nearly like that of the organic (4) than of the mineral soil groups.

CONTROL OF GREY SPECK

Wolverine oats were sown March 7, 1940, in a series of 2-gallon glazed jars containing a manganese-deficient alkaline organic soil used in an oxidation-reduction experiment. This experiment included the application of two manganese salts, two iron salts, and a control. These applications were made in January, 1939, and five crops had been grown previous to this crop. At approximately the same time,

a second experiment was set up in which the same soil had just received the application of the manganese salts. All treatments on both sets were replicated four times. The data relating to yield and occurrence of grey speck are presented in Tables 2 and 3.

TABLE 2.—*Effect of manganese and iron salt applications to an alkaline organic soil on the yield of Wolverine oats and on the prevention of the development of grey speck disease.*

Treatments January 1939, lbs. per acre*	Percentage of plants showing grey speck†								Yield in grams, av. of 4 jars
	March			April					
	29	30	31	1	2	3	4	26	
Control	5	45	74	84	93	96	99	100	41.2
$MnSO_4 \cdot 4H_2O$, 750	0	0	0	0	1	1	1	3	201.0
$Mn(C_2H_3O_2)_2 \cdot 4H_2O$, 700	0	0	0	0	0	1	1	5	187.9
$FeSO_4 \cdot 7H_2O$, 2,250	1	10	45	60	71	87	91	100	46.8
$Fe_2(SO_4)_3 \cdot 9H_2O$, 500	8	49	86	98	99	100	100	100	39.1

*The manganese salt applications have equivalent manganese contents.
†Oats sown March 7 and harvested as green oats on April 26, 1940.
Statistical analysis of yield data, F = 97.4. Number required for significance between means = 14.3.

TABLE 3.—*Effect of manganese salt applications to an alkaline organic soil at seeding on the yield of Wolverine oats and on the prevention of the development of grey speck disease.*

Treatments, lbs. per acre*	Percentage of plants showing grey speck†								Yield in grams, av. of 4 jars
	April							May	
	8	9	10	11	12	13	14	10	
Control	3	5	31	52	70	92	97	100	68.6
$Mn(C_2H_3O_2)_2 \cdot 4H_2O$, 700	0	0	0	1	1	1	2	3	118.2
$KMnO_4$, 900	0	0	0	0	0	0	0	0	152.0

*Potassium of $KMnO_4$ served as a part of the basic PK fertilizer. Manganese salts applied at rates in which manganese contents are not equivalent.
†Oats sown March 17 and harvested as green oats on May 10, 1940.
Statistical analysis of yield data, F = 158.9. Number required for significance between means = 10.7.

It is evident from these results that the application of manganese salts not only greatly increased the yield of green oats but also almost entirely prevented the development of grey speck disease. On the basis of plants showing lesions, it reduced the number of diseased plants to less than 5 out of every 100. All the plants on the control jars developed grey speck disease within a week after the appearance of the first lesion. The counts of diseased plants really do not give a complete picture, since each plant of the control showed many more lesions per plant than did the few affected on the manganese-treated soil. In most cases, several lesions appeared on each leaf of the controls. On the few affected plants grown on the soil receiving manganese salts, the infected areas were small and did not develop beyond the

primary stage. On these plants, only one lesion generally developed and that on the lower leaves.

The applications of manganese salts were not only beneficial in their control of grey speck, but they also prevented the development of chlorosis in the oats. The yield data in Table 2 show that the application of manganese sulfate and manganese acetate produced increases in yields of 388 and 356%, respectively. The yield data reported in Table 3 likewise show a very favorable growth response in the oats on those soils receiving an application of manganese salts.

Many research studies have been conducted by the junior author on manganese-deficient organic soils of Michigan during the past 15 years, with a continuous set of plots established for the past 7 years at the Muck Soil Experimental Field at Michigan State College. The results of these studies have shown that the chlorotic condition in oats, and in many other crops, which is produced by this deficiency can be cured by the application of manganese salts or by making the soil acid with sulfur flour. In addition to oats considered in this study, barley, rye and wheat have shown a depressed growth in the field trials, but the typical grey speck of oats has not been evident on the other grains. Instead, the plants have become chlorotic, with a longitudinal streaking which has progressed in from the tips of the leaves, often causing death of the leaves. Like oats, these other grain crops revive to some extent with hot weather. Fig. 3 shows the growth of oats and barley on these plots in 1941, while Table 4 presents the yields in the same year. On this same alkaline muck, manganese sulfate applied as a spray entirely corrected the chlorosis of the grain crops and grey speck of oats so that they made a normal growth.

TABLE 4.—*Effect of manganese sulfate and sulfur on yield of grain on alkaline organic soil, College farm, East Lansing, Mich., 1941.*

Av. plot Nos.	Special treatment*	Yield per acre			
		Gopher oats		Peatland barley	
		Grain, bu.	Straw, tons	Grain, bu.	Straw, tons
2, 5, 8, 11	Control	11.3	0.9	13.9	1.0
1, 4	$MnSO_4$	30.1	2.1	41.0	1.8
3,6	$MnSO_4$ + sulfur	37.9	2.1	46.3	1.9
7	Sulfur	27.4	1.9	33.4	1.8

*Uniformly fertilized with a 0-8-24 mixture.

A similar experiment was set up with oats in which the alkaline organic soil was treated to see if grey speck could be controlled by the same materials under greenhouse conditions. Applications of various manganese salts, sulfur, sulfuric acid, and hydroquinone were made to jars of a very manganese-deficient organic soil. Fig. 4 shows the growth of oats produced by these treatments, while Table 5 presents the data obtained.

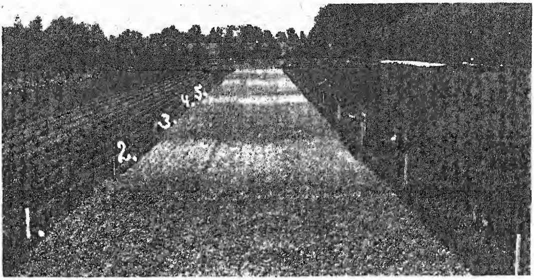

FIG. 3.—Gopher oats (left) and Peatland barley (right) growing on alkaline organic soil (ph 7.8) produced by burning over many years ago. Plots 2, 5, 8, and 11 were controls which showed practically 100% grey speck on the oats and an analogous chlorotic dieback of the barley, while the other plots (1, 3, 4, 6, 7, and 9) received either manganese sulfate or sulfur, or a combination, and the grain on them was entirely free from symptoms of malnutrition.

Practically complete prevention of grey speck disease, with no development of chlorosis in the oats, resulted from the applications of manganese sulfate, sulfur flour, sulfuric acid, and hydroquinone. The oats on the control jars were chlorotic and every plant had grey speck disease. Although the applications of pyrolusite gave no

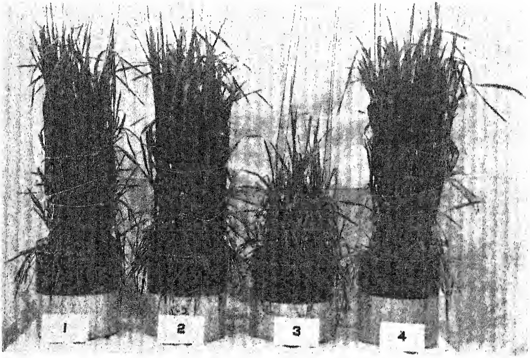

FIG. 4.—Effects of several materials on prevention of grey speck on oats. Applications of the following were made in pounds per acre: 1, hydroquinone, 2,000; 2, manganese sulfate, 350; 3, no treatment; and 4, sulfur flour, 4,000.

protection and of permanganate only slight reduction in amount of grey speck, they did prevent the development of chlorosis to some extent. The fact that permanganate applied at a heavier rate in the study presented in Table 3 gave as effective control as did manganese acetate, which in turn has appeared equal to manganese sulfate in other trials made by the authors, suggests that a more effective control could have been secured in the trials presented in Table 5 if a heavier application of the permanganate had been used.

TABLE 5.—*Effect of applications of several different materials on yield of Wolverine oats* and on control of grey speck disease.*

Treatments, lbs. per acre	pH of soil on March 3, 1941†	Condition of plants	Percentage of plants showing grey speck	Av. weight of green oats, grams
Control	7.39	Chlorosis + grey speck	100	78.3
$MnSO_4 \cdot 2H_2O$, 350	7.48	Normal	0	293.5
Pyrolusite (51% Mn), 2,000	7.36	Mild chlorosis + grey speck	100	123.7
$KMnO_4$, 416‡	7.28	Grey speck	77	137.6
Sulfur, 2,000	6.22	Normal	0	246.0
Sulfur, 4,000	5.64	Normal	0	249.7
H_2SO_4§	6.15	Normal	2	286.0
Hydroquinone, 2,000	7.43	Normal	0	251.2

*Oats were sown December 18, 1940, and harvested March 3, 1941.
†pH of all soils before treatments was 7.46.
‡Applied at same manganese equivalent as $MnSO_4$ application. PK fertilizer ratio altered to allow for K in $KMnO_4$.
§H_2SO_4 applied at a rate to equal the H_2SO_4 produced by a 2,000-pound per acre application of sulfur.
Statistical analysis of yield data, F = 106.7 Significance between means (5%) = 18.1.

The recent work of Griffith (3) and Jukes (5) indicate that the feeding of certain organic compounds is capable of controlling certain malnutritional disorders in poultry which have been caused by feeding rations containing an insufficient content of available manganese. A study was made to determine the effect of these organic materials on the growth of oats. In addition to these materials, the application of several organic and inorganic oxidation-reduction systems to the soil was studied as to their effect on the growth of oats and on the control of grey speck disease. The results of this study are given in Table 6, while Fig. 5 shows the growing crops. Creatinine, hemoglobin, stannous chloride, and sodium bisulphite were as effective in the control of grey speck disease as were either hydroquinone or manganese sulfate treatments. The yields of oats on the soils receiving creatinine and stannous chloride were higher than those obtained on the soil receiving manganese sulfate. The applications of thiamin chloride, methylene blue, choline, nickel acetate, and diphenyl carbazide did not control the development of grey speck disease in the oats. The oats on the control jars and on the soil receiving thiamin chloride were very chlorotic. Those receiving diphenyl carbazide failed to show typical grey speck but developed a brown color in the leaves extending from the tips toward the basal portions, appearing

as if the application were toxic to the crop. The oats receiving nickel acetate and choline showed a marked growth stimulation in their early growth but failed to maintain this rate of growth when the plants developed grey speck.

TABLE 6.—*The effect of applications of various organic reagents and strong reducing agents on the yield of oats and on the control of grey speck disease.**

Treatments, lbs. per acre	Av. yield, green oats, grams	Control of grey speck	Condition of plants
Control	52.7	No	Chlorotic
Manganese sulfate·$2H_2O$, 500	92.7	Yes	Normal
Hydroquinone, 2,000	98.1	Yes	Normal
Methylene blue, 2,000	65.6	No	Mildly chlorotic
Choline, 2,000	78.6	No	Slightly chlorotic
Creatinine, 2,000	109.8	Yes	Normal
Hemoglobin, 4,000	95.6	Yes	Normal
Thiamin chloride, 375	49.9	No	Very chlorotic
Stannous chloride, $2H_2O$†	100.7	Yes	Normal
Nickel acetate·$4H_2O$†	89.9	No	Normal
Sodium bisulfite†	95.6	Yes	Normal
Diphenyl carbazide†	51.1	No	Brownish leaves

*The oats were sown March 17 and harvested May 22, 1941.

†Applications were made on a theoretical oxidation-reduction potential basis (8), using manganese application as the basis, for example: $\left[\dfrac{Eo(Mn^{++} \longrightarrow Mn^{++++})}{Eo(Sn^{++} \longrightarrow Sn^{++++})}\right] \times Mn^{++}$ application $= Sn^{++}$ application.

The results of this experiment led one to speculate as to the role played by the various materials which were able to function apparently as manganese does in the plant nutritional processes. The question arises as to whether it is due to the direct action of the material or to its influence upon the availability of the manganese. Several of these materials were applied to a manganese-deficient soil of the same origin as the one used in the two preceding experiments. In 5 days after the application of the treatments, the soils were removed from the jars and determinations for water-soluble and exchangeable manganese were made in distilled water and neutral normal ammonium acetate leachates and the easily reducible manganese dioxide determined by the method described by Leeper (6). The results given in Table 7 show that those treatments which increased the exchangeable manganese in the soil above 3.0 p.p.m. were also the treatments which prevented the development of grey speck disease.

The water-soluble manganese was increased by applications of manganese carriers or by making the soil acid with sulfur or sulfuric acid. The quantity of water-soluble manganese is quite low and does not appear to follow either the yields or the efficiency of the control of grey speck disease. The easily-reducible manganese dioxide is increased markedly by the application of manganese compounds. The application of sulfur causes a small increase in exchangeable manganese and, when it is applied with manganese sulfate, it increases

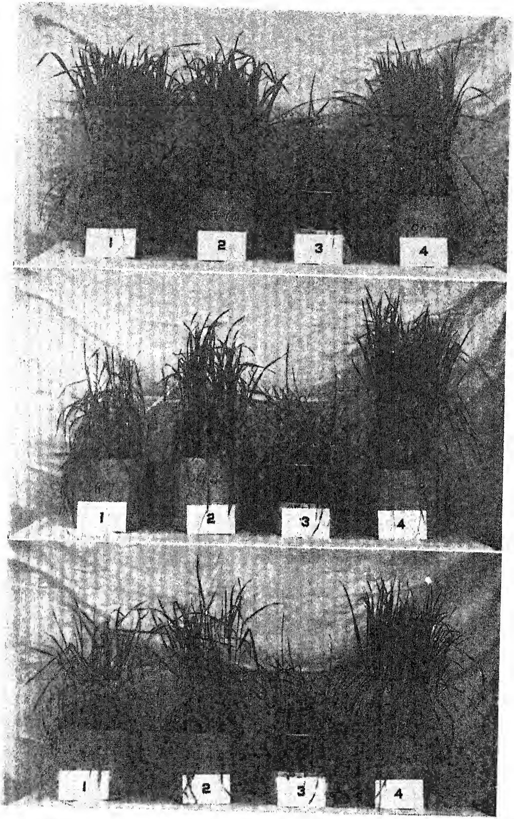

FIG. 5.—Effects of various applications to soil on the control of grey speck disease on oats. *Top:* 1, sodium bisulfite; 2, stannous chloride; 3, control; and 4, manganese sulfate. *Center:* 1, thiamin chloride; 2, choline; 3, control; and 4, creatinine. *Bottom:* 1, diphenyl carbazide; 2, methylene blue; 3, control; and 4, hydroquinone.

TABLE 7.—*Effect of the application of various materials to a manganese-deficient organic soil on the quantities of water-soluble and exchangeable manganese and the active manganic oxide.**

Treatment, lbs. per acre	pH of soil	Water-soluble Mn^{++}, p.p.m.	Exchangeable Mn^{++}, p.p.m.	Active MnO_2, p.p.m. Mn^{++}†	Prevention of grey speck
Control	7.39	0.2	1.6	15.0	No
$MnSO_4 \cdot 2H_2O$, 500	7.48	0.4	10.7	111.5	Yes
Pyrolusite (51% Mn), 2,000	7.36	0.2	2.3	28.8	No
$MnSO_4 \cdot 2H_2O$, 500 + sulfur, 2,000	6.09	1.6	17.2	108.7	Yes
Sulfur, 2,000	6.22	0.2	3.5	13.2	Yes
Sulfur, 4,000	5.64	0.3	4.2	11.2	Yes
H_2SO_4‡	6.15	2.5	4.8	14.1	Yes
Hydroquinone, 2,000	7.43	0.2	13.0	9.8	Yes
Methylene blue, 2,000	7.15	0.2	1.8	16.5	No
$SnCl_2 \cdot 2H_2O$, 1,000	7.22	0.2	5.3	15.2	Yes

*pH of all soils at the start of the experiment was 7.40. This soil contains 56 p.p.m. of manganese.
†Active MnO_2, as defined by Leeper (6), is the soil MnO_2 soluble in a solution of neutral ammonium acetate containing 0.2% hydroquinone after the water-soluble and exchangeable manganese have been removed.
‡H_2SO_4 applied at a rate to equal the H_2SO_4 produced by a 2,000-pound per acre application of sulfur.

this form of manganese very markedly so that it is higher than in the soil receiving manganese sulfate alone. The part which exchangeable manganese plays in the prevention of grey speck disease in oats is clearly demonstrated when one compares the analysis of the soils receiving hydroquinone and methylene blue. Hydroquinone treatment increases the exchangeable manganese to 8 times that of the control, while methylene blue has no effect whatever on this form of manganese. Since the application of hydroquinone is effective in controlling the development of grey speck disease, this effect must be through its action upon the soil manganese.

DISCUSSION

The results obtained in this work show the development of grey speck disease of oats to be a malnutritional symptom indicative of an insufficient supply of active manganese in the soil. The application of soluble manganese salts to the soil prevented the development of this disease on oat plants when they were grown during their normal growing season. Sulfur also proved to be an effective control when applied to the alkaline organic soils in quantities sufficient to change the reaction of the soil to a pH somewhat below 7.0. Field studies (4) have shown that a combination application of manganese sulfate and sulfur is not only very effective but also very efficient. Sulfur retards the oxidation of the manganese ion to inert oxides, and, by so doing, makes the manganese more available to the plant. In previous studies (8), plants grown on soils receiving this treatment showed a much higher manganese content than did those receiving manganese sulfate only.

It seems highly probable that any added material, such as sulfur, hydroquinone, creatinine, hemoglobin, or stannous chloride, which affects the yield of oats markedly and prevents grey speck does so by increasing the amount of exchangeable or active manganese in the soil. Any material which does not increase the amount of exchangeable manganese will not control grey speck. It is also conceivable that some materials, such as nickel acetate, might affect slightly the supply of exchangeable manganese so that the accompanying chlorosis would be checked, yet the effect on the manganese of the soil might not be sufficient to control grey speck.

Although this study has demonstrated that many materials will control grey speck, it is economically feasible to use only manganese sulfate or sulfur or a combination of the two. Studies made by the junior author (4) indicate that the advisability of using sulfur alone depends on whether the alkaline soil is well supplied with inactive manganese.

SUMMARY

In a study to determine the cause and control of a malnutritional disease which occurs on oats on manganese-deficient, alkaline, organic soil and on alkaline sandy soils of high organic content and which has not been reported in the United States, the following conclusions were drawn:

1. The physiological breakdown, ordinarily developed in oats on manganese-deficient soil, is the grey speck disease as it is recognized in Europe, Australia, and other countries.
2. The development of this breakdown is characterized by three successive stages, namely, "grey speck", "halo", and "dry spot". The stage which is likely to predominate will depend on climatic and soil conditions and on varietal characteristics.
3. Oats grown on a soil showing marked manganese deficiency will become chlorotic in addition to the development of grey speck disease.
4. The most practical method of preventing grey speck disease on an alkaline organic soil lies in the application of manganese sulfate at the rate of 100 to 400 pounds per acre or the application of sulfur in a quantity sufficient to lower the soil pH to a point somewhat below 7.0.
5. Experimentally, grey speck disease can be controlled by applying to the soil any manganous salt, permanganate, sulfur, sulfuric acid, hydroquinone, creatinine, hemoglobin, or stannous chloride. The data strongly indicate that any treatment which will increase the exchangeable manganese in this soil to 3 p.p.m. or more will prevent the development of grey speck disease. This can be accomplished by the addition of soluble manganese or by the reduction of manganic manganese to the manganous form by chemical means. The amount of exchangeable manganese in the soil necessary for the prevention of the development of the grey speck disease will vary with different soils, depending both on the pH value of the soil and on the active calcium supply.

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PHOSPHORUS FIXATION IN RELATION TO THE IRON AND ALUMINUM OF THE SOIL[1]

W. H. Metzger[2]

It has long been known that in soils of acid reaction phosphorus applied in relatively soluble form may be, at least in part, precipitated by iron or aluminum, or both. It has also been recognized that in slightly acid soils divalent bases, chiefly Ca and Mg, may account in part for fixation by bringing about precipitation of some of the applied phosphorus. In more recent years it has been suggested that adsorption may account in a large measure for fixation in the pH range 5.0 to 7.0, or more particularly in the range 5.0 to 6.0.

In a previous paper, the writer (4)[3] presented evidence indicating that relatively easily extractable iron and aluminum play an important part in phosphorus fixation. In some soils they appeared to account for a large part of the phosphorus-fixing capacity but in others much of the fixing capacity could not be accounted for in this way. This fact was also pointed out by Midgley (6). Further work aimed at additional clarification of this problem is reported in this paper.

MATERIALS AND METHODS

Soil samples taken from the various horizons of profiles of some of the prominent soil series of the Prairie zone of eastern Kansas were used in the work. These samples provided a wide range of contents of organic matter and of easily soluble and total iron and aluminum. Only those samples from the various profiles for which pH values fell in the range 5.0 to 7.0 were used in this work.

Phosphorus-fixing capacity was determined by shaking the soil samples for ½ hour in contact with a H_3PO_4 solution. The concentration of the solution used in each case was determined by the fixing capacity of the soil, stronger solutions being used for soils of high fixing capacity and weaker solutions for soils with low fixing capacity. The H_3PO_4 solution in each case was so adjusted in reaction with NaOH as to produce a suspension with the soil the pH value of which, at equilibrium, fell in the range 5.0 to 7.0. The pH value to which the solution was adjusted was approximately the same as that of the soil. To determine the amount fixed, the phosphorus remaining in solution was subtracted from that originally present. Total R_2O_3 was determined by fusing the soil with sodium carbonate, bringing the sesquioxides into solution and eventually precipitating, igniting, and weighing them. The residue from ignition was fused with potassium pyrosulfate and brought into solution. The iron was then recuded with a Jones reductor and titrated with potassium permanganate. Aluminum was determined by difference. Easily soluble iron and aluminum were determined by similar methods from extracts obtained by treating the soil with the dilute acid extracting solution (pH 3.0) used in the determination of available phosphorus by the Truog method (7).

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[3]Figures in parenthesis refer to "Literature Cited", p. 1098.

EXPERIMENTAL RESULTS

In Table 1 are presented the more pertinent data obtained from 42 samples representing 13 profiles. An examination of these data reveals relationships among some of the various factors studied. The extent of each of the relationships between various paired factors from Table 1 is shown in Table 2. From the correlation coefficients in Table 2 it is obvious that a close relationship exists between total R_2O_3 and the phosphorus-fixing capacity of the soil. Both total Fe_2O_3 and total Al_2O_3 show similar close relationships with fixing capacity. Fraps (3) found a high correlation between R_2O_3 extracted by strong acid and the phosphorus-fixing capacities for a large number of Texas soils.

The amount of easily soluble Fe_2O_3 present (soluble in Truog's extracting solution) shows no significant correlation with phosphorus-fixing capacity nor with the reduction of fixing capacity brought about by dilute acid extraction of the soil. When the reduction of fixing capacity was, in each case, expressed as percentage of the original value, these percentages were found to be highly correlated with the amounts of easily soluble Fe_2O_3. Likewise, a highly significant correlation was found to exist between the percentage reduction of fixing capacity occasioned by dilute acid extraction of the soil and the percentage of total Fe_2O_3 present in easily soluble form.

Since fixing capacity was found to be closely correlated with R_2O_3, total Fe_2O_3, and Al_2O_3, it appears that dilute acid extractable and nonextractable forms of both iron and aluminum function in phosphorus fixation processes in the soil. This conclusion is strongly supported by the fact that, although the amounts of dilute acid extractable Fe_2O_3 were not correlated with the quantitative reductions of fixing capacity induced by such extraction, the percentages of total Fe_2O_3 in easily extractable form were closely correlated with the percentages of reduction of fixation due to dilute acid extraction of the soil. This explains, in great measure, why the removal of free sesquioxides in previous work failed to destroy more completely the fixing capacity of the soil.

DISCUSSION

It may be readily observed from the data in Table 1 that a decidedly greater percentage of the total iron of surface horizons is easily soluble than in the lower horizons of the profile.

From the writer's viewpoint one of the most interesting and valuable relationships established by the data obtained in this work is the close correlation between the percentage of the total Fe_2O_3 which is dissolved in dilute acid and the percentage reduction in phosphorus-fixing capacity brought about by this dilute acid extraction of the soil. A scatter diagram showing this relationship is presented in Fig. 1.

The percentage reduction of the soil's phosphorus-fixing capacity which was induced when the soil was extracted with dilute acid was proportional to the percentage of the total Fe_2O_3 removed by this extraction. Furthermore, the soil horizons having high percentages

TABLE I.—*Sesquioxide content and phosphorus-fixing capacity of various horizons of several soil types.*

Soil type, horizon, and depth in inches	Total mgms per gram of soil			Easily soluble Fe_2O_3		Phosphorus-fixing capacity*	
	R_2O_3	Fe_2O_3	Al_2O_3	Mgms per gram of soil	Per-centage of total	Unex-tracted soil, p.p.m.	Acid-ex-tracted soil, p.p.m.
Cherokee silt loam:							
A_0, 0–4	85	26	59	3.7	14.0	36	17
A_1, 4–12	74	22	52	2.1	9.4	60	15
B_1, 20–23	192	50	142	2.1	4.3	263	174
B_2, 23–28	209	51	158	1.7	3.4	259	184
Geary very fine sandy loam:							
A_1, 3–9	171	30	141	2.6	8.4	102	37
A_2, 9–17	163	36	127	2.0	5.5	206	109
B, 17–27	166	38	128	1.6	4.1	214	114
Crete silt loam:							
A_1, 5–15	162	35	127	2.1	6.1	80	37
A_2, 15–19	151	40	111	1.9	4.7	107	62
Geary silt loam:							
A, 0–7	151	35	116	1.6	4.6	115	62
B, 6–18	176	46	130	1.3	2.9	216	144
Neosho silt loam:							
A_0, 0–2	54	16	38	1.4	8.6	30	17
A_1, 2–7	69	18	51	1.1	6.5	36	22
A_2, 7–14	85	23	62	0.7	3.4	77	60
B, 14	182	42	140	1.3	2.9	236	149
Labette silt loam:							
A_0, 0–2	152	43	109	2.7	6.3	87	57
A_1, 2–8	169	51	118	1.1	2.4	117	72
A_2, 8–16	163	48	115	0.9	1.9	135	92
B_1, 16–22	184	58	126	1.0	1.6	226	184
C, 28	212	72	140	0.7	1.0	411	361
Summit silt loam:							
A_1, 0–7	114	38	76	3.0	8.0	66	35
A_2, 7–9	142	46	96	1.3	2.9	140	97
Bates silt loam:							
A_1, 0–6	153	53	101	2.0	3.8	74	35
A_2, 6–8	198	65	133	2.0	3.0	140	97
C, 29	259	73	186	1.0	1.4	425	366
Boone, very fine sandy loam:							
A, 0–13	146	36	110	0.9	2.4	90	67
Knox silt loam:							
A, 0–9	151	38	113	1.0	2.6	125	85
B, 9–19	164	41	123	0.4	0.9	123	110
C, 19	169	46	123	0.2	0.5	123	102
Marshall silt loam:							
A_0, 0–2	141	32	109	1.8	5.7	47	37
A, 2–18	145	35	110	0.9	2.6	100	67
B, 18–32	161	37	124	0.6	1.6	157	110
C, 32	161	36	125	0.4	1.2	137	102

*The reductions in phosphorus-fixing capacity occasioned by extracting each soil with the extracting solution used in the Truog available phosphorus test are not shown as such in the table because of lack of space but may easily be calculated as the differences between the values of column 7 and those of column 8.

TABLE 1.—*Concluded.*

Soil type, horizon, and depth in inches	Total mgms per gram of soil			Easily soluble Fe_2O_3		Phosphorus-fixing capacity*	
	R_2O_3	Fe_2O_3	Al_2O_3	Mgms per gram of soil	Per-centage of total	Unex-tracted soil, p.p.m.	Acid-ex-tracted soil, p.p.m.
Grundy silt loam:							
A_0, 0–3	133	34	99	1.1	3.1	110	50
A_1, 3–15	162	39	123	0.9	2.3	171	122
B, 15–24	167	42	125	0.5	1.2	192	160
B_2, 24–30	179	42	137	0.5	1.2	192	166
C, 30	175	43	132	0.3	0.7	190	167
Carrington silty clay loam:							
A_0, 0–4	140	35	105	1.4	4.0	120	57
A_1, 4–16	145	38	107	1.0	2.7	210	102
B_1, 16–22	190	50	140	1.0	2.1	220	137
B_2, 22–30	207	53	154	0.8	1.4	235	214

*The reductions in phosphorus-fixing capacity occasioned by extracting each soil with the extracting solution used in the Truog available phosphorus test are not shown as such in the table because of lack of space but may easily be calculated as the differences between the values of column 7 and those of column 8.

TABLE 2.—*Correlations of various factors with the phosphorus-fixing capacity of soils.*

Factors correlated	Coefficient of correlation*
Total R_2O_3 with phosphorus fixing capacity	0.79
Total Fe_2O_3 with phosphorus-fixing capacity	0.73
Total Al_2O_3 with phosphorus-fixing capacity	0.75
Easily soluble Fe_2O_3 with phosphorus fixing capacity	-0.09
Easily soluble Fe_2O_3 with reduction of phosphorus-fixing capacity brought about by dilute acid extraction of the soil	0.05
Easily soluble Fe_2O_3 with percentage reduction of phosphorus-fixing capacity due to dilute acid extraction of the soil	0.66
Percentage of Fe_2O_3 that is easily soluble with percentage reduction of phosphorus-fixing capacity due to acid extraction of the soil	0.69

*Significant values at the 5% and 1% levels are .30 and .39, respectively.

of the total Fe_2O_3 extractable by dilute acid were those with high organic matter content, and *vice versa.* In view of this situation it would appear that organic matter must be very important in maintaining a portion of the inorganic phosphorus of the soil in a form which is soluble in dilute acid and probably available to plants. Meyer (5) held this to be true for Louisiana soils, but Doughty (2) has shown that organic matter of soils has little or no fixing capacity for applied phosphates. The organic matter itself, during the process of decomposition and mineralization of the organic phosphorus, may be the source of increased available phosphorus, but the relationships discussed above suggest strongly an influence of organic matter upon the soil's native, inorganic phosphorus. Organic matter exerts

a reducing effect upon the iron of the soil. Since iron in the soil is apparently so very active in fixing phosphorus, the organic matter of the surface soil appears to make an important contribution to phosphorus availability, possibly by maintaining a part of the iron combined with phosphorus in some reduced form, the availability of which is greater than that of $FePO_4$. In B and C horizons, where the amounts of organic matter are very small, phosphate is strongly held by iron in the ferric form with resulting low availability. That subsoils are almost invariably low in available phosphorus is well known.

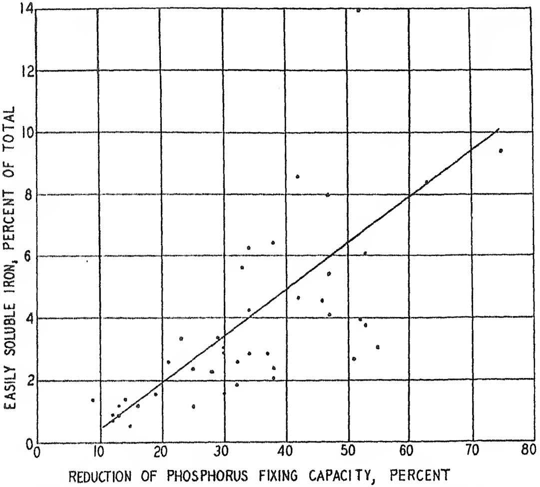

FIG. 1.—Relation of the percentage of total Fe_2O_3 of the soil that is easily soluble to the percentage reduction of phosphorus-fixing capacity brought about by extracting the soil with dilute acid.

The percentage of easily soluble aluminum does not vary with different horizons as does iron, but remains fairly constant. Since the soluble aluminum data show no significant relationship with the percentage reduction of phosphorus-fixing capacity resulting from acid extraction, they are not presented. Austin (1) has shown that aluminum hydroxide is much less active than iron hydroxide in rendering phosphate insoluble. The data obtained in this work indicate that the easily soluble aluminum of the soil is much less active than the easily soluble iron in fixing phosphorus.

SUMMARY AND CONCLUSIONS

The relation of total R_2O_3, Al_2O_3, and Fe_2O_3 of the soil and of the easily soluble fraction of each of these constituents to phosphorus fixation as measured in the pH range 5.0 to 7.0 has been studied and is reported. The data obtained reveal the following:

1. Total R_2O_3, Fe_2O_3, and Al_2O_3 of the soil showed in each case a highly significant correlation with phosphorus-fixing capacity.
2. Fe_2O_3 soluble in 0.002N H_2SO_4 (buffered to pH 3.0) was not significantly correlated with phosphorus-fixing capacity nor with the reduction of phosphorus-fixing capacity induced by extracting the soil with this dilute acid.
3. When the reduction of phosphorus-fixing capacity due to dilute acid extraction of the soil was expressed as percentage of the original fixing capacity, it showed a highly significant correlation with easily soluble iron.
4. The percentage of the total Fe_2O_3 which was in easily soluble form was highly correlated with percentage reduction of phosphorus-fixing capacity resulting from acid extraction. This was not true of aluminum, indicating that easily soluble aluminum of the soil must be much less active than easily soluble iron in fixing phosphorus.
5. Difficultly soluble iron in the form of silicates as well as easily extractable iron in the form of free oxides of the soil functions in phosphorus fixation. The same seems to be true of aluminum. This explains why removal of free sesquioxides from a soil may leave unaccounted for considerable of the original fixing capacity of the soil.
6. The greater availability of phosphate in surface layers of soils as compared to that in subsoils may be accounted for to a considerable extent by the reducing action of organic matter in the surface soil upon the iron combined with phosphate. This may maintain a portion of the phosphate in forms more readily available to plants than $FePO_4$.
7. The conclusion of a previous paper (4) is strongly corroborated, *viz.*, the phosphorus fixing capacity under field conditions of acid soils of the Prairie group, and probably other groups of acid soils as well, can be very largely accounted for by precipitation phenomena, while fixation at particle surfaces in a replaceable form is of slight practical significance.

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AN ASSOCIATION OF ROOT INJURY BY WHITE GRUBS, *PHYLLOPHAGA* SPP., AND LODGING OF CROSSBRED STRAINS OF CORN[1]

LEONARD C. HOEGEMEYER[2]

RESISTANCE to lodging is an important agronomic characteristic of most corn hybrids. Hybrids have been produced which are extremely resistant to both root and stalk lodging. Lodging in corn may be due to inherently deficient root development, weak stalks, or to damage caused by insect attack or disease.

Evidence demonstrating the resistance of certain corn hybrids to insect attack has been presented by Bigger, *et al.* (1),[3] Brunson and Painter (2), Dungan, *et al.* (4, 5), Meyers, *et al.* (7), and Snelling, *et al.* (8). This inherent physiological resistance of particular hybrid combinations has been observed frequently. Morphological characters also may contribute in repelling insect attack, according to Collins and Kempton (3) and McClelland (6).

Opportunity for the study of inherent resistance of corn hybrids to white grubs was presented in the occurrence of an attack of white grubs (*Phyllophaga* spp., one species was identified as *P. submucida*) in a replicated experiment designed to study agronomic characters among six inbred lines, their 15 possible single crosses, and 29 of the 45 possible double-cross combinations among them. The general interest in insect resistance and the particular suitability of the experiments attacked by the insects to a critical study of the behavior of related progenies led to the study of this problem.

PLAN OF FIELD EXPERIMENTS

Six inbred lines, having dissimilar agronomic characters, were crossed in all possible single-cross combinations. The inbred lines, originated from the Pride of Saline variety, are designated by the following pedigrees: K26, K41, K44, K54, K55, and K63. They had been used in the breeding program at the Kansas Agricultural Experiment Station previous to their inclusion in this study, had been inbred more than six generations, and apparently were homozygous for observable characters, including root lodging in the absence of root-feeding insects. Seed of some of the double crosses was produced in the greenhouse during the winter of 1937–38.

Six replications of each inbred line, single cross, and double cross were planted in plots 2 × 5 hills, the hills being spaced 42 inches in each direction. Each group of material was separated by suitable borders to eliminate excessive competition

[1]Contribution No. 323 from the Department of Agronomy, Kansas Agricultural Experiment Station, Manhattan, Kan., and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, cooperating. Received for publication August 11, 1941.

[2]Formerly Research Assistant in Agronomy, Kansas Agricultural Experiment Station, and Agent, U. S. Dept. of Agriculture. The author wishes to express his appreciation to A. M. Brunson of Purdue University who suggested the study and to R. W. Jugenheimer and H. H. Laude of the Department of Agronomy, and to R. H. Painter and H. R. Bryson of the Department of Entomology, Kansas Agricultural Experiment Station, for their assistance and suggestions.

[3]Figures in parenthesis refer to "Literature Cited", p. 1106.

and was distributed at random, with the single restriction that no group could appear more than once within each block. All plots were thinned to two plants per hill.

Severe root lodging occurred in many of the plots early in the fall, but no stalk breaking was evident. Examination of the plants and the surrounding soil revealed severe root injury and a uniform infestation of white grubs throughout the experimental area. On the average, six to eight grubs were found under each hill. The root lodging, uniform in nature, was attributed to second-year grubs of a species having a three-year cycle or to second-year grubs of a species having a two-year cycle. The grubs ordinarily do little damage during the hot, dry months of the summer season, but begin to do considerable damage during moist weather in the late summer and early fall after corn has nearly matured. The injury to the roots consisted of cutting the brace and the feeding roots. No strains were immune to grub damage. The data on lodging were obtained by individual plant counts in each of the replicated plots.

No injury by either western or southern root worm was detected during the growing season.

Analysis of variance was used to determine the statistical significance of differences obtained in this investigation.

RESULTS

The six inbred lines used in this study were not measurably injured by white grubs, as exemplified by little or no field lodging. Their respective acre yields and their lodging were as follows: K26, 0.4 bushel and 0.4%; K41, 7.8 bushels and 0.6%; K44, 14.5 bushels and 1.5%; K54, 6.6 bushels and 0.4%; K55, 17.7 bushels and 0.7%; and K63, 3.9 bushels and 0.3%.

The analysis of the data on lodging among the inbred lines is reported in Table 1. The differences among the inbred lines were not significant. None of the lines lodged to any appreciable extent.

TABLE 1.—*Analysis of variance of the data on lodging resulting from injury by white grubs to plants of six inbred lines.*

Source of variation	D/F	Sum of squares	Mean square	F value	1% level
Between replications....	5	67.81	13.56	6.25	3.86
Between inbred lines....	5	9.47	1.89	0.87	3.86
Experimental error......	25	54.36	2.17	—	—
Total.................	35	131.64	—	—	—

The roots of each of the six inbred lines were examined to determine comparative root injury. Representative roots of each line are shown in Fig. 1. The lines exhibit characteristic root development and show little root injury with the possible exception of inbred K55 (Fig. 1). It is not known whether the variation in the inbred K55 was due to inherent differences in root development existing within the line or to ununiform damage by the white grubs.

The single crosses exhibited varying amounts of injury in the field. The data on lodging for each single cross, the average yield of the

single crosses involving each inbred line, and comparable data on lodging and yield for Pride of Saline are reported in Table 2. The single crosses involving K54 lodged least as an average and those of K26 lodged most, while the variety Pride of Saline was intermediate in lodging.

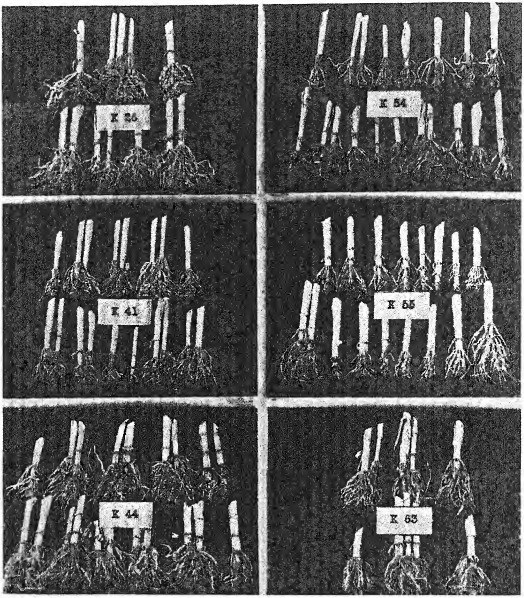

FIG. 1.—Characteristic root development and relative injury to roots by white grubs, *Phyllophaga* spp., of six inbred lines of corn, *viz.*, K26, K41, K44, K54, K55, and K63.

The analysis of variance of the data on lodging is shown in Table 3. The differences in lodging between single crosses and between replications were highly significant.

The single cross, K41 × K63, was severely injured by white grubs and was badly lodged in the field (Table 2). The least injured single cross was K41 × K54 which remained standing and was particularly conspicuous for that character in the field. The comparative injury

suffered by the roots of four single crosses is portrayed in Fig. 2. The plants of typical plots of the single cross K41 × K63 which was injured severely and of the single cross K41 × K54 which was least injured by grubs are shown in Fig. 3.

TABLE 2.—*Percentages of the plants of 15 single crosses and Pride of Saline that were lodged as a result of root injury by the white grub (Phyllophaga spp.) and the average yields of the crosses of each parental line.*

	K26	K41	K44	K54	K55	K63	Pride of Saline
K26	—	75.0	59.2	42.5	54.2	85.8	—
K41	75.0	—	52.5	20.0	34.5	86.6	—
K44	59.2	52.5	—	40.8	74.8	51.7	—
K54	42.5	20.0	40.8	—	33.3	36.7	—
K55	54.2	34.5	74.8	33.3	—	42.9	—
K63	85.8	86.6	51.7	36.7	42.9	—	—
Lodging av., %	63.3	53.7	55.8	34.7	47.9	60.5	40.8
Yield av., bu	31.3	35.1	33.2	29.4	36.0	31.4	32.7

TABLE 3.—*Analysis of variance of the data on lodging resulting from injury by white grubs to plants of 15 single crosses and Pride of Saline.*

Source of variation	D/F	Sum of squares	Mean square	F value	1% level
Between replications	5	316.93	63.39	4.07	3.27
Between single crosses	15	1373.07	91.54	5.88	2.29
Experimental error	75	1168.24	15.58	—	—
Total	95	2858.24	—	—	—

The root damage of individual single crosses was closely associated with the amount of lodging. The roots of each of the single crosses were examined. These root examinations revealed only moderate to slight root injury in the strains that lodged least, while in the strains that were lodged more severely a larger amount of root injury was evident. As a result of these root examinations, it is felt that the differences in root injury by the white grubs is largely responsible for the differences observed among the single crosses in standing ability.

The analysis of variance of the data on lodging for the double crosses as a result of injury by white grubs is shown in Table 4. The differences in lodging among double crosses are highly significant.

TABLE 4.—*Analysis of variance of the data on lodging resulting from injury by white grubs to plants of 29 double crosses and Pride of Saline.*

Source of variation	D/F	Sum of squares	Mean square	F value	1% level
Between replications	5	117.78	23.56	2.00	2.27
Between double crosses	29	1254.64	43.26	3.68	1.55
Experimental error	145	1709.89	11.79	—	—
Total	179	3082.31	—	—	—

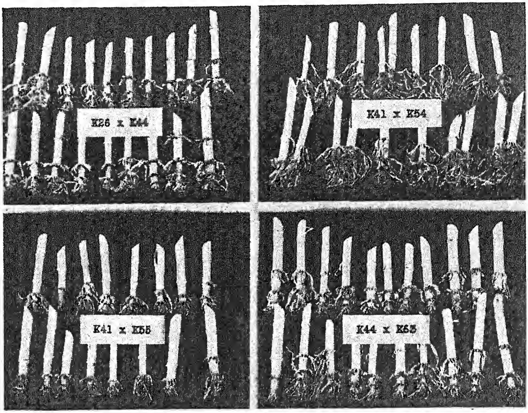

FIG. 2.—Characteristic root development and relative injury to roots by white grubs, *Phyllophaga* spp., of four single crosses, *viz.*, (K26 × K44), (K41 × K54), (K41 × K55), and (K44 × K63).

The root injury suffered by the double crosses ranged from 3.8 to 13.6%. The acre yield ranged from 21.6 to 30.4 bushels.

Among the double-cross combinations studied (K26 × K44) × (K41 × K54) was the least injured by white grubs and had few lodged plants, while (K41 × K55) × (K44 × K63) suffered the great-

FIG. 3.—Comparative field lodging of the single cross (K41 × K63) which was severely injured and the single cross (K41 × K54) which was least injured by white grubs, *Phyllophaga* spp.

est root injury by white grubs and lodged severely. The roots and plants of each of these double crosses, along with the original Pride of Saline variety, are shown in Fig. 4. The variety, as expected, is apparently comprised of plants which differ in their ability to withstand attack. The double-cross combination (K26 × K44) × (K41 × K54), shown in Fig. 4, was injured and lodged more severely than one of its single cross parents K41 × K54 (Figs. 2 and 3). The uniformity of the single cross in resistance to root injury and lodging is measurably lost in the succeeding double-cross combination.

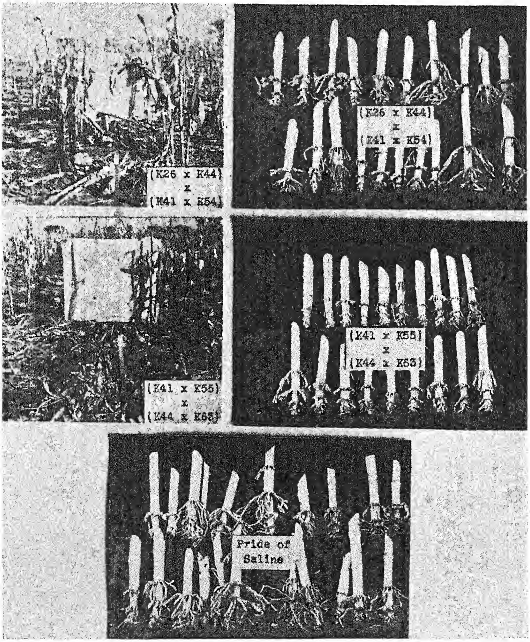

FIG. 4.—Comparative damage caused by white grubs, *Phyllophaga* spp., to roots and the subsequent lodging of the least injured double cross (K26 × K44) × (K41 × K54), the most severely injured double cross (K41 × K55) × (K44 × K63), and the intermediate injury of the Pride of Saline variety.

DISCUSSION

The roots of the inbred lines used in this investigation in general were not visibly damaged by white grubs and suffered only very minor amounts of lodging. The differences in lodging among the lines were not significant.

The single-cross and double-cross combinations involving these inbred lines differed significantly in the percentages of their plants that were root lodged, and these differences in lodging seemed to be a manifestation of differences in root injury by white grubs. The six parent lines differed markedly in the average percentages of lodged plants in the single crosses of which they were parents. Evidently they contributed genes to their crossbred progeny which influenced the amount of root injury and lodging suffered by their progeny even though no differences for these characters were evident among the parental lines themselves.

Hybrids which are high yielding may possibly lodge more easily than hybrids which are low yielding, due to greater ear size and weight. It has been shown (Table 2) that the higher yielding inbred lines in single-cross combination are intermediate in resistance to lodging, while the lowest yielding inbred line in single-cross combination is the most resistant to lodging. However, the existence of a relationship between high yield and high lodging or between low yield and low lodging of the single crosses and of the double crosses was not apparent.

The single crosses having the least root injury when combined gave the double-cross combinations which were least injured, whereas, the more severely damaged single crosses in combination gave double crosses which were more severely damaged by white grubs. Root injury and lodging were greater in the double crosses than in some of the least lodged single crosses involved in their parentage, as would be expected from the wide disparity in injury and lodging among the single-cross parents.

SUMMARY

In the study of resistance to damage by white grubs among the progeny of six inbred lines and all possible single and 29 of the possible double-cross combinations among them, differential root injury and lodging were detected.

Combinations of certain inbred lines resulted in some single crosses and double crosses which were superior and in others which were inferior in the amount of root injury by white grubs and in subsequent lodging.

Certain single crosses were less injured by white grubs than the double crosses involving them as parents.

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NOTE

THE INHIBITING EFFECT OF DEAD ROOTS ON THE GROWTH OF BROMEGRASS

IN connection with another investigation, bromegrass, *Bromus inermis* Leyss, and two other grass species were grown for 3 months in pure stands and in mixtures in sand watered with nutrient solutions. The total number of plants in each culture of the pure stands and mixtures was always the same. The nutrient solutions were identical but were replenished by the addition of the same amount of nutrient salts rather than changed during the course of the experiment. Under these conditions it was noted that the greater the proportion of bromegrass plants in the stands the smaller the dry weight of these bromegrass plants. At the close of the experiment analyses of the nutrient solutions indicated that these decreased dry weights were not due to mineral deficiencies occurring in the solutions. This suggested the possibility that when bromegrass is grown a substance, or substances, inhibitory to its own growth accumulates in the substratum, which in the above experiment had accumulated in the unchanged nutrient solutions. It also seemed that such a substance could either be excreted from the living roots, liberated from the dead cells sloughed from the living roots, or formed by the decomposition of these dead cells.

With these points in mind plants of bromegrass were grown in 2-gallon crocks filled with quartz sand with which 0, 7, and 25 grams, respectively, of oven-dried roots were thoroughly mixed. The seeds were planted in the sand on March 7 and the plants harvested on April 22, 1941. The plants in all treatments were watered with a nutrient solution known to give good growth of bromegrass. The solutions were applied by the hand-operated system described by Withrow and Biebel.[1] The dry weights of the plants in the various treatments are shown in Table 1. Each value is the mean of 12 replications of 10 plants each.

TABLE 1.—*Dry weights of bromegrass plants grown with nutrient solutions in sand containing various amounts of dead bromegrass roots.*

Grams of dead oven-dried roots per 2-gallon crock	Dry weight per plant in grams		
	Roots	Tops	Total
0 (check)	0.207	0.489	0.696
7	0.146	0.336	0.482
25	0.039	0.056	0.095

Statistical analysis of the data showed the reductions in the dry weights of the plants in the different treatments to be highly significant. Tests made at the close of the experiment showed a greater

[1]WITHROW, R. B., and BIEBEL, J. P. A subirrigation method of supplying nutrient solutions to plants growing under commercial and experimental conditions. Jour. Agr. Res., 53:693–702. 1936.

amount of nitrate nitrogen and other nutrients present in the solutions applied to the sand containing the dead roots than in those applied to the pure sand. Thus, the results cannot be explained on the basis that the organic material mixed with the sand resulted in the tying up of the available nitrogen or other nutrients. The roots mixed with the sand were dried at 120° C for 2 hours then to a constant weight at 60° C, so it does not appear likely that they introduced any microorganisms. which attacked the plant. Thus, the results of this preliminary experiment suggest that a substance, or substances, is derived from the dead roots of bromegrass which greatly inhibits the growth of this grass. It is proposed to study further the chemical and physical nature of these growth-inhibiting substances and their effect on plant growth.

Pure stands of bromegrass are notorious for reaching a so-called "sod-bound" condition; that is thick stands for no apparent reason tend to thin out after a few years. This has been blamed on a too dense root growth and on nitrogen deficiency in the soil. The preliminary results presented here indicate that sod-binding of bromegrass might at least in part result from the accumulation of growth-inhibiting substances in the soil.—H. M. BENEDICT, *Cheyenne Horticultural Field Station, U. S. Dept. of Agriculture, Cheyenne, Wyoming.*

BOOK REVIEWS

THE SECOND YEARBOOK OF RESEARCH AND STATISTICAL METHODOLOGY

Oscar Krisen Buros, Editor. Highland Park, N. J.: The Gryphon Press. Ed. 2. XX + 383 pages. 1941. $5.

REVIEW of the first volume of this work occurs in JOURNAL, Vol. 31 (1939), page 992. The second yearbook not only exceeds the first by 283 pages, but it is printed in larger type which makes easier reading. The pages are larger and the binding is buckram. Additional features are a List of Cooperating Journals; Periodical Directory and Index; and Index of Titles. It lists a total of 359 books, written in English since 1933, of which 125 were listed in the first volume. This repetition was made to include reviews of books that appeared since the publication. It contains 1,652 review excerpts from 283 journals compared with 635 review excerpts from 131 journals in the first volume. The excerpts are also longer and more representative than heretofore.

The only criticism the reviewer has to offer is the one also made regarding the first volume, namely, the lack of a list of subject matter in each book. Many workers are located at smaller institutions or substations and thus are rather isolated from the large statistical libraries of certain universities. If they desire to secure the works they need, which of the books should they buy, especially if they are interested not only in the usual phases of statistics but also in certain special problems? Lists of subject matter would be of immense help in knowing in what works the desired information could be found. Then, careful reading of the review excerpts would help in making the selection. It occurs to the reviewer that a numerical code could be used economically for listing the subject matter of most books, with the use of titles for special subjects if necessary. By reducing the size of the excerpts it might be possible to include such lists without increasing the publication costs.

In spite of this criticism, the reviewer holds the book in high esteem. The selection of reviews has been extensive and seems to be fair in giving the different views of the writers. Moreover, sufficient of each review has been presented to give the reader a good idea what each reviewer thought of any particular book. The editor is to be commended on the excellence of the publication. Since he states in the preface that the possibility of future editions depends on the sale of this second volume, it would seem that every worker who is interested in the use of statistical methods should purchase a copy and thus assist in the continuation of this excellent series. (F. Z. H.)

THE CHEMICAL FORMULARY (Vol. V)

H. Bennett, Editor-in-Chief. Brooklyn: Chemical Publishing Co., Inc. XVIII+676 pages. 1941. $6.

WHILE these volumes are primarily written for the manufacturing chemists, agronomists, as well as all scientists dealing with material and apparatus, are in frequent need of a recipe of one sort

or another. This well-indexed fifth volume of the Formulary, which is an addition to and not a new edition of the previous volumes, contains thousands of clearly written formulae, including chapters on adhesives, emulsions and dispersions, farm and garden specialties, food, lubricants, materials of construction, metals and metal treatment, photography, rubber, resins, plastics, and waxes.

Most of the 21 chapters include an up-to-date general discussion of the subject in addition to the recipes. Inasmuch as such formulae are not at all available in the scientific literature and to a limited extent only through handbooks, these volumes will often be very useful to all engaged in experimental research. (Z. I. K.)

FELLOWS ELECT FOR 1941

HOWARD BENNETT SPRAGUE

OUR first Fellow tonight is distinguished by his versatility and his eager participation in anything agronomic.

He is a teacher, a researcher, and at times an extension specialist. During the last 15 years there have been few if any meetings of the Society in which this man has not actively participated. He has served as committeeman and helped formulate some of the crops programs for the annual meetings.

His research contributions have been in the fields of alfalfa breeding, corn breeding, fine turf investigations, pasture improvement, root studies and others. He is interested particularly in a physiological approach to agronomic problems. Some of his former students and others say that this man is such an enthusiastic agronomist that he even spends his recreation time thinking and doing things of an agronomic nature.

Gentlemen I am glad to present Howard B. Sprague as a Fellow of the Society.

DAVID WIELD ROBERTSON

OUR next Fellow was born at Dumfriesshire, Scotland, in 1893. He was granted the degree of B.S. in Agriculture by the University of Manitoba in 1918, the degree of M.S. by the University of Minnesota in 1920, and the degree of Ph.D. by the University of Minnesota in 1928.

His principal interests are in the field of genetics and plant breeding, but he has also made important contributions to knowledge of crop plant physiology and cultural practices. His best-known work relates to genetics. Due principally to his efforts, our knowledge of barley genetics exceeds that of any other of the small grains.

Less well known but perhaps not less important are his studies of chlorosis in irrigated wheat, critical periods for the application of irrigation water, the use of sugar beet petioles as indicators of soil fertility needs, field plot technic, breeding varieties of wheat and barley for the dry plains of eastern Colorado, delayed germination in the cereals, the effect of long-time storage on the viability and the milling and baking quality of wheat, and the relation of humidity to the viability, moisture content, and respiration of seed wheat, oats, and barley in storage.

Since 1920, he has served as Associate Agronomist and as Agronomist at the Colorado State Agricultural College and the Colorado Agricultural Experiment Station. He is now in charge of experimental agronomy, David Wield Robertson.

EDMUND LOUIS WORTHEN

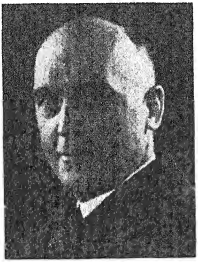
OUR next Fellow is a graduate of the University of Illinois. He was a student and great admirer of Cyril G. Hopkins. He obtained his M.S. degree from Cornell University in 1908. He served on the Illinois Soil Survey and with the Soil Survey Division of the U. S. Dept. of Agriculture.

He was engaged for a short period in fertilizer investigations with the North Carolina State Board of Agriculture. He taught soils at the Pennsylvania State College for five years. He is the author of a widely used text on "Farm Soils." He has been a life-long student of fertilizer problems. He is a member of the Society's Fertilizer Committee.

Since 1919 he has been in charge of extension work in agronomy at Cornell University and is a recognized leader in soils extension work.

Proof of his long-time interest and service to the Society is the fact that he is listed among her charter members. If you turn to Volume 25, page 7, of the JOURNAL you will see what he looked like at the time the Society was founded, Professor E. L. Worthen of Cornell.

EDWIN BROUN FRED



OUR next Fellow, Edwin Broun Fred, was born in 1887 in Middleburg, Va. He received the B.S. and M.S. degrees from the Virginia Polytechnic Institute and the Ph.D. degree from the University of Göettingen, Germany, in 1911.

Assistant in Bacteriology, 1907–08, and Assistant Professor of Bacteriology, 1912–13, Virginia Polytechnic Institute; Assistant Professor of Bacteriology, 1913–14, Associate Professor of Agricultural Bacteriology, 1914–18, Professor of Agricultural Bacteriology since 1918, and Dean of the Graduate School since 1934, University of Wisconsin.

Fellow A.A.A.S., member of the American Society of Agronomy, National Academy of Science, Society of American Bacteriologist (President in 1932), and Sigma Xi. Author and co-author of numerous scientific journal articles and of several books dealing with soil bacteriology, root nodule bacteria, and fermentation.

It is difficult to assess the value to agronomy of a many-sided person like Dean Fred. He has in the past through personal research done a tremendous amount in the related field of soil microbiology and particularly in the relations of nodulation of leguminous plants to symbiotic nitrogen fixation. He has trained, or participated in the training, of many soil scientists, who continue in this field. In spite of administrative duties in the last few years, Dean Fred has maintained

his active interest in the science of the soil, the affairs of the Agronomy Society, and in teaching his class in soil bacteriology.

GORDON G. POHLMAN

OUR last Fellow received his B.S., M.S., and Ph.D. degrees at Iowa State College. For several years he was associated with the University of Arizona as Assistant Soil Chemist. Since 1930 he has been associated with the West Virginia University.

His contributions, both as an investigator and a teacher in the fields of soil bacteriology and soil fertility, as well as his services to the Society, make him a worthy recipient of the honor being given him tonight.

Doctor G. G. Pohlman, Head of the Department of Agronomy and Genetics at West Virginia University and Secretary-Treasurer of the Society since 1938, has not only contributed much to soil science, but he has rendered, especially during the past three years, outstanding service to our Society.

MINUTES OF THE THIRTY-FOURTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF AGRONOMY

THE THIRTY-FOURTH ANNUAL MEETING of the Society was held in the Mayflower Hotel in Washington, D. C., November 12, 13, and 14. There were 571 members and guests registered in attendance at the meetings which were held jointly with the Soil Science Society of America.

The general meeting of the Society was held Thursday morning, November 13, with President L. E. Kirk presiding. Dr. L. H. Newman, Dominion Cerealist for the Department of Agriculture, Ottawa, Canada, gave a very interesting paper on "The Retention of B Vitamins in Flour and Bread". This was followed by another paper of equal merit on "The Soil Scientist Looks Ahead" presented by Dr. F. E. Bear, Head of the Department of Agronomy, Rutgers University. Both papers were well received and will be published in the JOURNAL.

At the annual dinner of the Society held Thursday evening President L. E. Kirk presented the presidential address on the subject "The Agricultural Scientist and the War" which appears in this number of the JOURNAL.

The Crops Section had a general session and eight subsectional meetings at which 45 papers were presented. In addition, they sponsored a trip to the Beltsville Research Center on Friday afternoon.

The Soil Science Society of America had one general program and 15 sectional programs at which 84 papers were presented.

A joint meeting of interest to both soils and crops men was held on Friday morning. At this session six papers were presented on the general subject of "Pasture Fertilization and Management".

The Auditing Committee appointed by President Kirk consisted of Dr. W. B. Kemp and Dr. F. L. Duley. The Nominating Committee consisted of President Kirk, Chairman, Dr. R. J. Garber, Dr. C. J. Willard, Dr. William Albrecht, and Dr. R. W. Cummings.

FELLOWS ELECT

Vice President Richard Bradfield announced the Fellows Elect and presented certificates at the annual dinner on the evening of November 13. The following were elected Fellows of the Society: E. B. Fred, G. G. Pohlman, D. W. Robertson, H. B. Sprague, and E. L. Worthen.

NOMINATING COMMITTEE REPORT

The nominating committee made the following report: Dr. H. J. Harper, Oklahoma A. & M. College, and Dr. Ide P. Trotter, Texas A. & M. College, as representatives of the Society on the council of the American Association for the Advancement of Science; and Dr. F. D. Keim, University of Nebraska, for Vice President of the American Society of Agronomy.

Upon motion from the floor the Secretary was instructed to cast one vote for these nominees and they were declared unanimously elected.

Respectfully submitted,
G. G. POHLMAN, *Secretary.*

OFFICERS' REPORTS

REPORT OF THE EDITOR

THE 1941 volume of the JOURNAL will make quite a substantial addition to the agronomist's library. It will contain 12 more papers than the 1940 volume, 12 more notes, and 3 more book reviews, which taken together represent an increase in text pages over last year of considerably more than an average-sized number of the JOURNAL. In other words, subscribers to the JOURNAL will receive a dividend on their investment this year in the way of added pages of agronomic literature as compared with recent volumes.

The quality, too, has been improved, we believe, under the present system of rigid review exercised by the Editorial Board; at least, several comments to that effect have been received during the year. The present review system has its shortcomings, some of which we hope to smooth out as we go along, but on the whole it is the most satisfactory procedure yet devised for handling JOURNAL manuscripts. We find that without exception authors welcome constructive criticism, and there is no question but that the critical review to which all contributions to the JOURNAL are now subjected as a matter of routine results in greater condensation and "meatier" papers.

The Editorial Board passed on something like 155 papers during the year, and has done its work expeditiously and conscientiously and is deserving of the sincere thanks of the Society for the excellent performance of a rather tedious job.

As a matter of record of the make-up of the 1941 volume of the JOURNAL as compared with the 1940 volume, we present the following tabulation:

	1940	*1941**
Published Papers	109	121
Published "Notes"	17	29
Published Book Reviews	13	16
Papers Under Review	11	16
Papers Approved and Awaiting Publication	12	9
Papers Returned to Authors	17	21
Totals	179	212

*As of October 1, but figures for published papers, etc., are complete for the 1941 volume.

At this time (November 1) sufficient papers have been approved for publication to complete the February 1942 number of the JOURNAL and papers now in the hands of the Editorial Board will account for one or two additional numbers. Publication within four or five months after submission of the manuscript is a reasonable expectation in the JOURNAL at present, but this interval may be lengthened if many of the papers presented at this meeting are offered for publication.

A substantial gain in advertising has been realized during the year due to the efforts of our advertising solicitors, Macfarland and Heaton of New York City.

Indications now are that much of the 1941 gain will be held during 1942, with still other new accounts in sight. This increased advertising revenue, coupled with the sustained support of the JOURNAL by members of the Society and by subscribers, has made possible the additional pages in the 1941 volume without unduly straining our finances. Unquestionably, the greatest service the reader can render to the JOURNAL in its efforts to develop and maintain income from advertising is to patronize advertisers in the JOURNAL whenever possible and to let advertisers know that their copy has been seen and read.

Last year, in the December number of the JOURNAL, we published a "Guide to Contributors to the Journal of the American Society of Agronomy", and we believe that we can see the benefits of this in the papers coming in to the JOURNAL now. Many more of them than formerly are better organized and conform more nearly to the style of the JOURNAL. Reprints of this "Guide" are still available for the asking.

Perhaps contributors to the JOURNAL would be interested to know more specifically the basis upon which their contributions are reviewed by the Editorial Board. First of all, it should be understood that, with very few exceptions, contributions are accepted for publication in the JOURNAL only from members of the American Society of Agronomy or the Soil Science Society of America. This is a policy of long standing and is based upon the premise that the JOURNAL is primarily a membership publication and is supported to a very large extent by membership fees. It has long been a requirement, therefore, that those who wish to use the pages of the JOURNAL as a medium of publication should help support it. As a rule, only original papers are accepted; dissertations, review types of papers, and highly controversial papers are not desired. The paper may deal with research, teaching, or extension, but it should represent a real contribution in its field.

Each paper received in the Editor's office is recorded and then referred at once either to the Associate Editor for Crops or the Associate Editor for Soils who, in turn, sends it to the Consulting Editors, and possibly other persons, best qualified to pass judgment on the subject matter. The first question the reviewer is asked to answer is, "Does this paper present *something new and worth* while in its field that readers of the JOURNAL would welcome?" Additional points which the reviewer is asked to consider are as follows:

Do the data bear out the conclusions drawn? The reviewer is told that the author must assume responsibility for all calculations and should leave nothing to surmise. Where statistical interpretation of the data is attempted, care should be exercised to see that the correct procedure is followed and that the proper deductions are made.

Are the tables well organized? Superfluous data are not wanted. Well-arranged and readily understood tables save much space in presenting results, but poorly organized tables are a source of annoyance and waste.

Are the illustrations, if any, essential to an understanding of the text? Illustrations cost too much to be used merely to embellish the text. A good illustration, on the other hand, may save much space in description or narrative. "Your story in pictures leaves nothing untold" is the slogan of the photo-engraver employed to make the cuts for the JOURNAL; but even so, we do not expect to see the JOURNAL become a pictorial magazine. The half-tone reproductions in the JOURNAL will never be any better than the original copy from which they are made, and in fact are seldom quite as good. Because of the economy in paper stock that must be practiced in printing the JOURNAL, it is essential that photographic copy to be

reproduced in the JOURNAL be exceptionally clear and contrasty. Some contributors make a practice of presenting their results both in tabular form and by means of graphs. There is seldom justification for presenting the same data both ways. The choice of method of presentation should be based upon the importance attached to the detailed data. Tables, of course, offer an opportunity to present data in more detail, while graphs visualize the result.

Are the literature citations excessive in number? Long literature reviews are the bane of every technical journal, especially in the publication of theses. Yet there is justification at times for a rather extensive review of the literature, especially in new fields of investigation. In writing for this JOURNAL, however, it should be borne in mind that one is addressing an audience exceptionally well informed on the literature and generally only the most pertinent references will be justified.

These and other considerations engage the attention of the reviewer who brings to bear upon the manuscript the point of view of a disinterested reader, but one well qualified to pass judgment upon the value of the results and upon the method of presentation. His comments are almost always constructive and are well worth the careful consideration of the author. It is much better to meet any challenge that might be leveled at one's paper *before* publication than to have to face possible adverse criticism *after* publication. One closely identified with a problem may not see the forest for the trees and thus may benefit greatly from the comments of an observer who views it from a distance and without the manifold details that loom so large on intimate contact.

The policies which have guided the JOURNAL to a successful conclusion during 1941 will be continued through 1942, and, all things being equal, we trust that another successful year lies ahead of us.

Respectfully submitted,

J. D. LUCKETT, *Editor*.

REPORT OF THE SECRETARY

THE membership changes in the Society during the past year may be summarized as follows:

Members, November 1, 1940		1,176
New members, 1941	139	
Reinstated members	13	
Total increase	152	
Dropped for non-payment of dues	100	
Resigned	27	
Died	2	
Total decrease	129	
Net increase		23
Membership, October 31, 1941		1,199

The changes in number of subscribers are as follows:

Subscriptions, November 1, 1940		594
New subscriptions, 1941	95	
Reinstated subscribers	63	
Subscriptions dropped	84	
Net increase		74
Subscriptions, October 31, 1941		668

The paid up membership and subscription list by states and countries is as follows:

	Members	Subscriptions
Alabama	19	1
Arizona	11	6
Arkansas	10	6
California	50	15
Colorado	21	1
Connecticut	13	4
Delaware	4	1
District of Columbia	86	7
Florida	24	4
Georgia	19	5
Idaho	7	2
Illinois	56	15
Indiana	30	4
Iowa	41	4
Kansas	44	4
Kentucky	14	4
Louisiana	18	5
Maine	6	1
Maryland	21	4
Massachusetts	13	4
Michigan	25	5
Minnesota	35	5
Mississippi	14	3
Missouri	19	5
Montana	7	6
Nebraksa	37	4
Nevada	5	1
New Hampshire	3	1
New Jersey	17	6
New Mexico	8	2
New York	44	16
North Carolina	29	7
North Dakota	15	1
Ohio	54	7
Oklahoma	16	6
Oregon	19	3
Pennsylvania	22	9
Rhode Island	7	0
South Carolina	19	2
South Dakota	11	1
Tennessee	17	4
Texas	53	15
Utah	19	8
Vermont	3	1
Virginia	26	2
Washington	22	5
West Virginia	11	1
Wisconsin	40	2
Wyoming	6	1
Alaska	1	1
Hawaii	7	9
Philippine Islands	1	2
Puerto Rico	4	3
Africa	4	23
Argentina	8	17
Australia	0	27
Belgian Congo	0	3
Bolivia	0	1
Brazil	2	5
British Guiana	0	1
British West Indies	0	1
Canada	25	44
Ceylon	0	3
Chile	2	3
China	3	19
Colombia	2	1
Cuba	3	1
Denmark	2	0
Dutch East Indies	0	7
Egypt	0	1
England	0	13
Fed. Malay States	0	5
Fiji	0	1
Finland	0	4
Germany	0	5
Greece	1	1
Guatemala	1	0
Haiti	2	
Honduras	1	1
India	2	20
Indochina	0	1
Ireland	0	1
Italy	0	1
Japan	1	86
Mauritius	0	1
Mesopotamia	0	1
Mexico	0	3
New Zealand	0	6
Norway	0	2
Palestine	1	1
Persia	1	0
Peru	0	4
Portugal	0	6

	Members	Subscriptions		Members	Subscriptions
Scotland	2	2	Uruguay	1	0
Spain	0	1	Russia	0	14
Sweden	0	2	Venezuela	1	2
Switzerland	1	1	Wales	0	3
Thailand	2	2			
Turkey	0	1	Total	1,191	589

The increase in number of both total and paid up members of 23 and 38 respectively is encouraging. Actually I believe we now have more paid up members than at any time in our history. We have only 32 less members on our rolls than we had in 1938 at which time we had 1,230 members but only 1,074 of those were paid up, whereas we now have 1,191 who are in good standing. This represents an increase of 117 paid up members in the past four years.

The policy of dropping members on July 1 who have not indicated their intention of paying dues has been continued. As a result we now have only 8 unpaid members. All of these have indicated their intention of paying 1941 dues as soon as possible. Quite a number of members have resigned from the society. Some of these have been called by the army and will undoubtedly renew their membership when they return to civilian life. The number dropped for nonpayment of dues is still high and we should try still harder to keep our members. One old member retained is just as good as one new member. The state representatives and other members have been active in securing 138 new members. Their cooperation is greatly appreciated. Keep up the good work.

The number of paid up subscriptions has held up remarkably well in spite of world conditions. At present there is one less paid up subscriber than there was a year ago. There are 79 additional subscribers who have ordered the JOURNAL but whose payment has not been received. Most of these are in the U.S.S.R. and the orders are for the last half of the year. They have already paid for the first half of the year and it is quite probable that these will be paid soon as we have received some payments within the past month. For the most part, loss of subscriptions in countries under German domination have been counterbalanced by gains in other countries. I hope that the subscription list can be maintained during the coming year.

Respectfully submitted,
G. G. POHLMAN, *Secretary.*

REPORT OF THE TREASURER

I BEG to submit herewith the report of the Treasurer for the year ending October 31, 1941.

RECEIPTS

American Society of Agronomy	$13,705.08
Soil Science Society of America	4,919.50
International Society of Soil Science	480.00
Endowment Fund, International Society of Soil Science	13.05
Total receipts	$19,117.63
Balance on hand, October 31, 1940	2,686.23
Total income	$21,803.86

DISBURSEMENTS

American Society of Agronomy		$13,596.64
Soil Science Society of America		4,080.78
International Society of Soil Science		20.00
Total disbursements		$17,697.42
Balance on hand, October 31, 1941	$4,106.44	
Balance in trust certificates	267.71	
Balance in savings bonds	2,400.00	
Total assets, October 31, 1941		$ 6,774.15

These assets are divided as follows:

	Cash	Trust Certificates	Savings Bonds	Total
American Society of Agronomy	$1,093.48	$148.51	———	$1,241.99
Soil Science Soc. of America	500.47	———	———	500.47
Marbut Memorial Fund	980.09	119.20	———	1,099.29
International Soc. Soil Science	1,315.48	———	———	1,315.48
Endowment Fund (I.S.S.S.)	216.92	———	$2,400.00	2,616.92
Total assets, October 29, 1941	$4,106.44	$267.71	$2,400.00	$6,774.15

A breakdown of receipts and expenditures of the American Society of Agronomy for the year ended October 31, 1941, is as follows:

RECEIPTS

Miscellaneous	$ 76.25
Convention receipts	1,085.70
Advertising	1,211.53
Reprints sold	1,911.04
Journals sold	115.54
Subscriptions, 1940	336.55
Subscriptions, 1941 (old)	2,462.94
Subscriptions, 1941 (new)	364.23
Subscriptions, 1942 (advanced)	173.40
Dues, 1940	212.00
Dues, 1941 (old)	4,961.48
Dues, 1941 (new)	732.92
Dues, 1942 (advanced)	52.50
Index	9.00
Total receipts	$13,705.08
Balance on hand, October 31, 1940	985.04
Total income	$14,690.12

DISBURSEMENTS

Printing the JOURNAL, cuts, etc.		$9,462.43
Salary of Business Manager and Editor		750.00
Postage, Business Manager and Secretary		260.86
Printing, miscellaneous		200.97
Express		.45
Mailing Clerk and Stenographer		1,282.24
Refunds, checks returned, etc.		104.45
Expenses for meetings		1,256.79
Miscellaneous		278.45
Total disbursements		$13,596.64
Total income	$14,690.12	
Less total disbursements	13,596.64	
Balance in checking account, October 31, 1941	$ 1,093.48	
Balance in trust certificate	148.51	
Total assets		$ 1,241.99

In spite of present world conditions, the Society is in better financial condition than it was a year ago when we had only $985.04 in the checking account. It is hoped that increased support of the Society in the countries not at war will at least maintain our present financial condition.

Respectfully submitted,
G. G. POHLMAN, *Treasurer.*

REPORT OF THE AUDITING COMMITTEE

THE Committee have examined the books of the Treasurer of the Society, and find the accounts correct as reported.

The Committee would like to suggest that the Executive Committee of the Society consider the audit of these books by a certified public accountant at least once every five years.

W. B. KEMP
F. L. DULEY, *Chairman*

OTHER COMMITTEE REPORTS

VARIETAL STANDARDIZATION AND REGISTRATION

DURING the year, the following approved varieties were accepted by the Committee for registration on the basis of performance:

WHEAT

Rival (Reg. No. 329), developed by the North Dakota Agricultural Experiment Station.

OATS

Otoe (Reg. No. 98), developed by the Nebraska Agricultural Experiment Station.

Tama (Reg. No. 99), developed by the Iowa Agricultural Experiment Station and the U. S. Department of Agriculture.

Marida (Reg. No. 100), developed by the Idaho Agricultural Experiment Station and the U. S. Department of Agriculture.

BARLEY

Beecher (Reg. No. 12), developed by the Colorado Agricultural Experiment Station and the U. S. Department of Agriculture.

Lico (Reg. No. 13), developed by the Colorado Agricultural Experiment Station.

Texan (Reg. No. 14), developed by the Texas Agricultural Experiment Station and the U. S. Department of Agriculture.

SORGHUM

Norkan (Reg. No. 79), developed by the Kansas Agricultural Experiment Station and the U. S. Department of Agriculture.

A. C. Arny	L. F. Graber	W. J. Morse
H. B. Brown	H. K. Hayes	T. R. Stanton
J. A. Clark	E. A. Hollowell	T. M. Stevenson
E. F. Gaines	R. E. Karper	G. H. Stringfield
		M. A. McCall, *Chairman*

PASTURE IMPROVEMENT

GRASSLAND CONFERENCES

YOUR Committee has continued to encourage and assist with the holding of Grassland Conferences as outlined in the 1940 report. A Regional Conference was held at Mandan, North Dakota, the last week in June. It was very successful in attendance as well as in quality of papers, demonstrations, and discussions.

Following the summer conferences held last year, the hope was expressed that the Regional Grassland Conferences would stimulate the holding of state and local conferences in order that the problems and methods for grassland improvement might be brought more directly to the farm and ranch operators. Several state institutions held Grassland Conferences this past year. "Grassland Days" and symposia were a part of the annual program of various society group meetings. Industrial organizations also encouraged and actively participated in grassland meetings.

State conferences were held in conjunction with regional meetings of technical workers at Raleigh, North Carolina, and Pullman, Washington, and summer meetings of the Agronomy Society at Lafayette, Indiana and Durham, New Hampshire. Other professional organizations, particularly the livestock group, are giving special consideration to "Grassland Days" and symposia at their annual and summer meetings. All of these developments are bringing about a greater appreciation of the need for research on problems related to the shift toward a grassland agriculture.

The program and activities of your Pasture Committee during the past year have been facilitated by the cordial cooperation and support of the local institutions where the meetings were held, and by the many people throughout each region who presented papers and participated in the program. The publicity organizations too did a fine job of supporting the Conferences. Your Committee is very grateful indeed for all of this assistance.

DEVELOPMENT OF METHODS AND TECHNIC FOR GRASSLAND RESEARCH

The Pasture Improvement Committee of the American Society of Agronomy is cooperating with The Joint Pasture Research Committee in the development of material for An Outline on Methods and Technic for Grassland Research. A very successful conference of the Joint Pasture Research Committee was held at Chicago last fall, immediately following the annual meeting of the American Society of Animal Production. At that time arrangements were made for bringing together data and other material from various society and group meetings pertaining to research methods with pastures and ranges. This is a rather large undertaking involving many people. The material for the publication is being received very slowly and consequently will be delayed probably until some time in 1942.

H. L. AHLGREN	ROBERT LUSH
B. A. BROWN	T. M. STEVENSON
D. R. DODD	(for O. MCCONKEY)
C. R. ENLOW	GEORGE STEWART
C. M. HARRISON	J. D. WARNER
	O. S. AAMODT, *Chairman*

BIBLIOGRAPHY OF FIELD EXPERIMENTS

THE Committee has compiled a bibliography of 71 titles of the more important contributions on the methodology of and interpretation of results of field plat experiments, either reported since or not included in the revised bibliography published in the JOURNAL (Vol. 25:811–828, 1933; and the additions in Vol. 27: 1013–1018, 1935; Vol. 28:1028–1031, 1936; Vol. 29:1042–1045, 1937; Vol. 30: 1054–1056, 1938; Vol. 31:1049–1052, 1939; Vol. 32:984–986, 1940).

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F. R. IMMER
H. M. TYSDAL
H. M. STEECE, *Chairman*

FERTILIZERS

Subcommittee on Fertilizer Application.—The subcommittee on fertilizer application has continued to participate in the work of the National Joint Committee on Fertilizer Application. During the past year the work of the latter committee has continued to deal with machine placement of fertilizers and experimental work is still underway in a number of states. Special interest has developed in the results to be obtained from deep incorporation of fertilizers accomplished either by deep drilling or plowing under, the purpose being to escape the immobilization of nutrients that follows the disiccation of the surface soil in dry weather. Studies to date appear promising and further work is contemplated.

Other new aspects of the fertilizer application work have dealt with the use of starter solutions and the addition of fertilizers in irrigation water. Outstanding results have been obtained by the use of starter solutions in some states during the year whereas meager or negative effects have been obtained in others. The need for further work is recognized.

Considerable progress has been made during the year in the development and improvement of mechanical equipment for the practical application of fertilizers in conformity with the principles established by research.

R. M. SALTER, *Chairman*

Subcommittee on Fertilizer Grades.—Through cooperation of agronomists and the fertilizer companies, data have been collected from 27 states concerning the number of grades sold, total tonnage, tonnage of recommended grades, and sales of grades containing less than 20% plant food. Sales of recommended grades varied from 1.7% to 100% of total tonnage sold. Grades containing less than 20% plant food constituted from 3.2% to 91.1% of total sales.

The subcommittee urges a more general utilization of recommended grades, and of grades containing 20% or more of plant food. Restricted use of transportation facilities emphasizes the importance of higher grade fertilizer. The guaranteeing of minor element content, consideration of a ratio system for selection of grades, limitation of the % of N, K_2O, or of $N+K_2O$ to 8%, are points under consideration. Closer cooperation between agronomists and the industry, in many states, is strongly recommended.

C. E. MILLAR, *Chairman*

Subcommittee on Fertilizer Reaction.—Meetings of the subcommittee on fertilizer reaction were held in December, 1940 and February, 1941. The following problems were selected for study during 1941:

1. The relation of the equivalent acidity and calcium content of fertilizers to potato scab.

2. The relation between the salt or osmotic index of fertilizers and their influence on the germination and stand of cotton.

Investigations on the fertilizer potato scab problem were conducted by Dr. W. A. Albrecht of Missouri and Dr. H. T. Cook of the Virginia Truck Station. In addition, a survey of the influence of soil conditions and soil fertility practices on the prevalence of potato scab was made for the Northwestern states and the South Atlantic states.

Studies on the relation between the salt index of fertilizers and their influence on the germination and stand of cotton have been conducted by Dr. J. J. Skinner of the Bureau of Plant Industry and the North Carolina and Georgia Agricultural Experiment Stations.

F. W. PARKER, *Chairman*

Subcommittee on Malnutrition in Plants.—It is with a considerable degree of satisfaction that the subcommittee reports the publication entitled "Hunger Signs in Crops". The prepublication sale of 6,232 copies at $2.00 per copy encouraged the sponsors to print an edition of 14,000 instead of 10,000 as originally planned. Since publication 2,028 copies have been sold at $2.50 per copy. There were on hand about 5,000 copies on October 9, 1941 to be disposed of, and since that date sales have been progressing satisfactorily. The above figures indicate that the publication is justifying itself.

J. E. MCMURTREY, *Chairman*

Subcommittee on Soil Testing.—Reports and tabulation of data presented at last year's meeting have been reviewed. The comparative study of soil tests on check soils has been concluded. A final revised summary will be prepared for publication in the JOURNAL of the Society.

During the year, a member of the subcommittee has made a correlative study of fertilizer recommendations based on soil tests, as reported by several soil testing agencies, for a group of soils from a Southeastern state. The results indicated that the recommendations were influenced greatly by the agronomic background of the interpreter of the test, thus giving much greater divergence in the proposed treatments than the soil test differences seemed to warrant.

The subcommittee notes with much interest the excellent survey of soil testing in the various states and provinces recently conducted by the Department of Field Husbandry, of the Canadian Department of Agriculture. In the light of this work, no further survey of the current use and attitudes toward soil testing is needed in this country at present.

Recent new publications contributing to soil testing advancement are as follows:

Bul. 398, Pa. Agr. Exp. Sta.
Bul. 106, Va. Truck Exp. Sta.
Bul. 450, Conn. Agr. Exp. Sta.
Publ. of South African Sugar
Technologists—by Beater, B. E., "Estimation of the Availability of Phosphorus, Potash and Nitrogen in Soils by a New, Rapid Technique"

It has become apparent to this subcommittee that matters of chemical technic in soil testing should be the primary concern of Section II, of the Soil Science Society, and of the Association of Official Agricultural Chemists, rather than of the Fertilizer Committee as now constituted. From the latter's standpoint, soil testing is intimately related to other information that can be applied to

diagnosing the nutrient status of the soil, such as: malnutrition symptoms of crops, plant tissue tests and the inherent soil properties identifiable with soil type.

In view of the need for a better understanding of the mutual role of investigations in these several lines, it is proposed that this subcommittee be dissolved, to be replaced by a subcommittee of broader interest to deal with all aspects pertaining to diagnosing fertilizer needs of individual soils and crops.

M. F. MORGAN, *Chairman*

At the meeting of the Fertilizer Committee as a whole on November 11 the need for correlating the work on malnutrition symptoms with that of soil testing and tissue testing was discussed and the proposal of the subcommittee on soil testing that a single subcommittee to deal with diagnosis of nutrient deficiencies and excesses be set up received general support. Accordingly, the Committee recommends that the subcommittees on malnutrition in plants and on soil testing be discontinued and that a new subcommittee be set up to deal with all phases of the diagnosis problem.

R. M. SALTER, *Chairman*

STUDENT SECTIONS

CHARTERS in the Student Section of the American Society of Agronomy have been granted to 23 institutions as follows: Iowa State College, Kansas State College, Oklahoma A. & M. College, University of Illinois, University of Minnesota, University of Nebraska, Brigham Young University, Utah State College, Texas A. & M. College, Mississippi State College, Clemson College, Louisiana State University, Michigan State College, Pennsylvania State College, Colorado State College, North Dakota Agricultural College, Virginia Polytechnic, University of Tennessee, University of New Mexico, Ohio State University, Southwestern Louisiana Institute, North Carolina State College, and University of Georgia.

More than 300 certificates of membership were issued to individual student members in the various states during the past year. The student organization issues a national news letter three times each year.

In the national essay contest on the subject, "The Role of Legumes in Agriculture", cash awards of approximately $50 go to each of the three highest ranking contestants. The winners of the fourth, fifth, sixth, and seventh places will receive cash awards of $20, $15, $10, and $5, respectively. The first three winners will be given appropriate medals. All awards are made possible through the generosity of the Chicago Board of Trade.

The 10 ranking contestants and their schools follow: Daniel Atkinson, University of Nebraska; Charles Gardner, University of Nebraska; Jeffery E. Dawson, University of Florida; Dale Weibel, University of Nebraska; Robert E. Wagner, Kansas State College; Earl Ragsdale, University of Illinois; Jack Carter, University of Nebraska; Paul E. Smith, Kansas State College; Chester Crofton, Kansas State College; and Theodore Sommer, University of Illinois. Abstracts of the first, second, and third prize papers are appended to this report.

The Committee recommends the continuation of the essay contest next year and urges the members of the Society to stimulate more wide participation. Nearly all of the essays are entered from three or four schools. If this report is approved the topic for next year's essay will be announced in an early issue of the JOURNAL.

GEO. H. DUNGAN
J. B. PETERSON
M. B. STURGIS
J. W. ZAHNLEY
H. K. WILSON, *Chairman*

THE EFFECTS OF LEGUMES ON ASSOCIATED AND SUCCEEDING CROPS

Daniel Edward Atkinson, University of Nebraska

FOR well over two thousand years, farmers have observed beneficial effects of legumes on other plants. The study of these effects has been one of the most fertile fields of agricultural research during the past half-century.

Legumes were found in most virgin grassland, where they appear to have played a significant role in the soil nitrogen economy. They have been found to be of preeminent importance in the establishment and maintenance of high-yielding tame-grass pastures.

The yield and protein content of either native or introduced grasses can be increased by association with pasture legumes. The yield of grass is frequently doubled, and a large amount of additional forage is obtained from the legume. Such association commonly raises the protein content of grasses 20 to 40 per cent. Total protein production is increased considerably more than this because of the protein in the legume. Nitrogenous fertilizers, through decreasing the legume-grass ratio, usually lower the total protein production and may even reduce the total yields of mixed pastures.

Cereals are not often benefited by association with legumes. On the contrary, grain yields are ordinarily decreased by mixed cropping. Such mixed crops, however, may favorably affect yields in following seasons.

Crop rotations including legumes have been shown to be nearly indispensable in avoiding the decline in yields which inevitably accompanies continuous cropping. By the judicious use of legumes, cereal yields may be maintained or increased.

Winter green manure crops in the South frequently double the yields of succeeding cash crops, and beneficial effects may persist several years. Under most conditions, leguminous plants are much more valuable for green-manuring purposes than are non-legumes.

North of the range of adaptation of winter legumes, inclusion of a legume in the rotation entails a smaller cash-crop acreage. Despite this fact, rotations containing legumes have been demonstrated to be essential in the development of profitable long-time farming systems for the Corn Belt and areas to the east.

In semi-arid regions, the use of a legume in the rotations is not justified unless water is supplied. Under irrigation, however, very striking increases in crop yields are observed following legumes.

In all parts of the country, yields of continuously cropped land show alarming decreases. Under many conditions, the maintenance of crop yields at levels which make profitable agriculture possible may be best effected by the utilization of legumes in carefully planned rotations.

LEGUMES—UNDERGROUND NITROGEN-FIXATION FACTORIES

Chas. O. Gardner, University of Nebraska

ALTHOUGH there are about 75 million pounds of nitrogen above every acre of land and sea, to most plants it is as useless in this gaseous form as sea water is to a thirsty man. Just as salty water must be distilled before drinking, nitrogen must be "fixed" before it is of any use to growing plants. With a few exceptions only the diverse members of the *Leguminosae* family with their associated *Rhizobia* bacteria can perform this amazing feat of chemical magic known as nitrogen-fixation.

The role of legumes in restoring nitrogen to the soil is of inestimable value to agriculture. It has been calculated that they contribute between one and two million tons of nitrogen annually to the soils of the United States. Most crops following legumes show definite increases in both yield and in protein content except in areas of low rainfall.

Even ancient civilizations before the birth of Christ recognized the value of rotating cereal crops with legumes, but the discovery of symbiotic nitrogen-fixation in 1886 by Hellriegel and Wilfarth added impetus to their popularity.

Undoubtedly the process of symbiotic nitrogen-fixation involves one of the most important biochemical reactions now being investigated by scientists engaged in agricultural research. It has furnished a fertile field for scientific investigation as the physiology and biochemistry of the fixation process are as interesting and intriguing as they are perplexing. A multitude of publications have appeared but so many of them are of a controversial nature that definite conclusions cannot be drawn.

Investigations have definitely proved that neither the legume plant nor *Rhizobia* bacteria can fix nitrogen independently of the other. The true symbiotic state must exist before fixation can take place.

The entrance of the bacteria into the root and the subsequent development of the nodule is not too thoroughly understood. Recent cytological studies of 31 species have shown root nodules to contain the tetraploid (4n) number of chromosomes instead of the usual diploid (2n) number.

An extensive study of bacterial strains has indicated that some plants will symbiose simultaneously with several strains of *Rhizobia*, while other plants appear somewhat restricted as to the number of strains with which they will symbiose. This has been shown to be related to pollination, which if valid will place symbiosis on a heritable basis.

The actual biochemical mechanism of fixation is unknown. It may proceed by the way of ammonia or through hydroxylamine, or the nitrogen molecule may react directly with carbon compounds to form amino acids, amides, or proteins. The hydroxylamine hypothesis is supported by the most evidence and is the most widely accepted.

Whether nitrogenous compounds are excreted from root nodules has been much disputed. Virtanen seemingly demonstrated that l-aspartic acid is excreted, but other investigators have failed to duplicate his results. Further studies on excretion may throw some light on whether there is any real basis for the belief that mixed cropping is advantageous.

Many other phases of symbiotic nitrogen-fixation have been studied, but definite conclusions cannot be reached in all cases. The rapidity with which the practical application of these biochemical studies can be made depends upon the success of research workers in clearing up existing uncertainties.

THE ROLE OF LEGUMES IN FLORIDA AGRICULTURE

Jeffery Dawson, University of Florida

LEGUMES can be grown economically in Florida during both summer and winter. This creates many opportunities for the adaptation and use of legumes as forage, cover, catch and green-manure crops.

Winter legumes play an important role in the Florida forage crop program for at least three reasons. First, winter clovers furnish abundant and nutritious feed during the late winter and early spring when grasses are producing very little

feed. Second, the grasses commonly used in pastures respond to nitrogen fertilization because of the low nitrogen content of Florida soils; legumes may be used to supply nitrogen to these grasses. Growing legumes with pasture grasses increases the yield of pasture herbage by stimulating the grass and by producing leguminous forage on the pasture. Third, Blaser and Boyd (Fla. Agr. Exp. Sta. Bul. 351, 1940) show that the addition of clover to grass pastures increases the nitrogen, calcium and phosphorus content of the feed.

The usefulness of winter cover crops in Florida is limited by two factors, when summer cash crops are to follow. First, no legume has been found that will produce a large quantity of organic matter before it must be plowed under in preparing the soil for the following summer cash crop. Second, few legumes have been found that will seed, under Florida conditions, prior to spring cultivation. These two factors do not, necessarily, limit the usefulness of winter cover crops in pecan, tung oil or citrus groves.

Summer cover crops exert two very important influences on the soil. First, a summer cover crop reduces wind erosion. Second, a summer cover crop decreases losses due to leaching. This latter effect is very important in Florida because of heavy summer rains. Among the summer cover crops grown in Florida are such legumes as Crotalaria, (*C. striata* and *C. spectabilis*); Velvet beans (*Stizolobium deeringianum*); cowpeas (*Vigna sinensis*); and Beggarweed (*Desmodium purpureum*).

Peanuts (*Arachis hypogea*) are grown both as a catch and as a main crop. They are especially adapted to loose sandy soils because of their growth habit. Peanut vines make hay of high quality. Peanuts are used in the making of peanut butter, oils and peanut meal. Pork production in Florida is largely dependent upon peanuts as a source of feed.

Green-manuring helps to maintain the nitrogen content of a soil, to furnish energy material for the microorganisms and to maintain a desirable condition of tilth. Crotalaria, Velvet beans and Beggarweed are grown as green-manure crops in Florida; all of these crops will grow on poor sandy soils.

Hence, legumes are important in Florida as forage, cover, catch crops, and green manure crops.

SOIL TILTH

THE previous reports of this joint committee have dealt with problems associated with the concept of tilth. It is the purpose of this report to suggest a method of action whereby some basic information on tilth can be obtained through the joint efforts of representatives of the American Society of Agronomy and the American Society of Agricultural Engineers.

Your chairman had the opportunity of discussing such joint efforts with the chairman of a similar committee in the American Society of Agricultural Engineers, Mr. I. F. Reed, from the Tillage Machinery Laboratory at Auburn, Alabama. As a result of our discussions, together with other comments from different individuals interested in soil tilth, the following recommendations are made:

1. That as a beginning in a program of tilth research, the Joint Committee between the American Society of Agronomy and the American Society of Agricultural Engineers serve as a technical planning group for research in soil tilth to be carried on in cooperation with the tillage laboratory at Auburn and that the program of tilth research be discussed and approved by this committee.

2. That such a tilth research program include the study of porosity and soil penetration measurements in conjunction with the tillage measurements on plots that have been treated in various ways to change the tilth of the soil; plants should be grown on selected plots to determine the relation between soil tilth and plant growth. In this way, it will be possible to obtain plant growth, soil data and engineering data on the same soil.
3. That the President of the American Society of Agronomy appoint a new committee on soil tilth, the personnel being so chosen as to represent the research division of the Bureau of Plant Industry as well as the state Agricultural Experiment Stations and that this committee meet with a similar committee from the American Society of Agricultural Engineers to develop plans for action on this important subject. Such plants should eventually include all agricultural areas where tilth problems are of paramount importance.

H. E. MIDDLETON — I. F. LUTZ
R. J. MUCKENHIRN — L. D. BAVER, *Chairman*

EXTENSION PARTICIPATION

OUR Committee wishes to make the following report:

We appreciate the emphasis which has been placed at this meeting on the interpretation and application of agronomic research.

The Committee, reporting for the Extension group, recommend to the Society the appointment of a standing committee composed of research and extension men from important seed-producing and seed-using areas to correlate the production and utilization phases of improved strains of forage crops.

J. C. LOWERY — E. L. WORTHEN
O. S. FISHER — E. R. JACKMAN
EARL JONES — L. L. COMPTON
J. S. OWENS, *Chairman*

RESOLUTIONS

THE Committee on Resolutions regrets to announce the passing of two members of the American Society of Agronomy during the past year, Dr. Anton L. Frolik of Nebraska and Dr. J. W. Tidmore of Alabama. Doctor Frolik was on leave from the University of Nebraska and was serving as a Major in the Army at Fort Leavenworth, Kansas. He fell from a horse in November 1940 and suffered a brain concussion. He died from a blood clot which formed a few months later. Doctor Tidmore was killed in an automobile accident while in the field discharging his many duties. Both of these young men were outstanding in their field.

On behalf of the American Society of Agronomy the Committee makes this announcement with sorrow and a feeling of real loss to the Society and to their respective families. Detailed accounts of the lives and attainments of Doctor Tidmore and Doctor Frolik are attached to this report.

O. S. AAMODT — J. D. LUCKETT, *ex-officio*
F. N. BRIGGS — F. D. KEIM, *Chairman*
R. I. THROCKMORTON

ANTON L. FROLIK

NEBRASKA lost one of its most outstanding young teachers on January 27, 1941, with the death of Dr. Anton L. Frolik at Fort Leavenworth, Kansas. He was 33 years old.

Born at DeWitt, Nebraska, Doctor Frolik received a bachelor's degree in agronomy at the University of Nebraska in 1928 and a master's degree in 1930. He was awarded the degree of doctor of philosophy by the University of Wisconsin in 1936.

In June 1934 he was married to Rose Marie Novak. To them was born a son, Richard. He is 3½ years of age.

A major in the officers' reserve corps, he had been on leave of absence from his position as associate professor in agronomy at the University of Nebraska, College of Agriculture, since October 1, 1940, when he was called to active duty with the United States Army.

An autopsy revealed the cause of death was a cerebral hemorrhage, the result of a head injury when he was thrown from a cavalry horse, November 5. The fact that he had been ill with influenza since the first of January made an earlier diagnosis difficult.

Dr. Frolik was in charge of receiving recruits at Fort Leavenworth and gave promise of a brilliant record there rivaling his academic career, according to officers at the Fort. Brigadier General E. L. Gruber, commandant of the Fort, told relatives that, "The reception center for recruits at Fort Leavenworth stands as a monument to Major Frolik's work. He had an unusually creative mind, and did an excellent job in helping to set up this center."

The University of Nebraska crops judging teams coached by Doctor Frolik won first place in national competition at Chicago five times since 1930; and first at Kansas City four times during the same period.

Doctor Frolik was intensely interested in pasture and range research. He was particularly interested in the Nebraska Sandhill vegetation and was the author of numerous articles and research bulletins in this field. He was noted for his ability as a public speaker and was always in demand.

Doctor Frolik was a member of Alpha Zeta, Gamma Sigma Delta, Sigma Xi, Phi Sigma Sem. Bot., the American Society of Agronomy, the Ecological Society of America, and the Farm House fraternity.

We have lost an outstanding teacher and research worker. Doctor Frolik was a most popular teacher and had the ability to pass on to his students his great enthusiasm for knowledge. He possessed the highest type of integrity. He believed that every teacher should be a living example of all character-building principles. His popularity caused most of his students to copy these principles and build them into their lives.

JAMES W. TIDMORE

THE tragic death of Doctor J. W. Tidmore which occurred in a collision between his car and a truck on Highway U. S. 80 west of Selma, Alabama, on July 24, brings an irreparable loss not only to his state and the South, but also to the entire country where he was recognized as an authority in agronomy and soil research. Doctor Tidmore was head of the Agronomy and Soils Department and Associate Director of the Agricultural Experiment Station and Alabama Polytechnic Institute at Auburn, Alabama.

James Wallace Tidmore was born in Havana, Alabama, in December 1898.

He graduated at Auburn receiving a B.S. degree in 1919, a M.S. degree in 1924, and a Ph.D. degree from the University of California in 1928. He was with the college at Auburn as instructor from 1919 to 1924; assistant professor from 1924 to 1926; associate professor from 1928 to 1933; appointed head of agronomy and soils in 1933 and assistant director of the Experiment Station in 1938.

Doctor Tidmore made many contributions to the welfare of farmers and the improvement in agriculture. Perhaps his outstanding contributions were on sources of nitrogen and fertilizer formulas for cotton and the use of limestone as a filler in mixed fertilizers. As a result of the latter research, he succeeded in having enacted into law the requirement that all fertilizer manufacturers selling in Alabama label their materials either acid-forming or nonacid-forming.

He was married to Miss Sarah Mardre on November 15, 1922. Mrs. Tidmore, a daughter Sarah, 12, and a son Wallace Jr., 8, survive.

The deceased was a member of the Methodist church and vice-chairman of the Board of Stewards. He was a member of the following fraternal orders and societies: Masons, Kiwanis, Pi Kappa Alpha, Gamma Sigma Delta, Phi Kappa Phi, Sigma Xi, American Society of Agronomy, and Soil Science Society of America.

Taken from us when his vigorous efforts were being crowned with success in his service to his fellowmen, we are proud that he has lived.

MONOGRAPHS

THE Committee on Monographs was appointed at the request of the Committee on Monographs of the Land Grant College Association. It is composed of three members appointed by the President of the Soil Science Society of America and three members appointed by the Chairman of the Crops Section of the American Society of Agronomy. The Committee was unable to meet as a whole, but each of the above groups met separately. Both groups arrived independently at the following conclusions:

1. That there is real need for a series of monographs covering certain important but specialized fields in field crops and soil science.
2. That well-qualified men are interested in writing such monographs.
3. That a committee on monographs should continue to (a) serve as a clearing house for suggestions regarding needed monographs; (b) keep present interest in monographs alive and to catalyze further thought along this line; and (c) continue the study of possible methods of getting these needed monographs published.

R. BRADFIELD, *Chairman*

For Crops:	For Soils:
O. S. AAMODT	W. H. PIERRE
E. N. FERGUS	R. M. SALTER
H. H. LAUDE	O. C. MAGISTAD

HISTORY OF THE AMERICAN SOCIETY OF AGRONOMY

"NOTES on the History of the Society" (this JOURNAL, Vol. 23 (1931), page 1035) and the "History of the Origin of the American Society of Agronomy" (this JOURNAL, Vol. 25 (1933), pages 1 to 9), as prepared by T. Lyttleton Lyon, give an interesting and excellent presentation of the origin of the Society and the changes which took place during the first 25 years of its existence. "Origin, Aim, and Organization of the American Society of Agronomy" (this JOURNAL, Vol. 33

(1941), pages 478–479) by the author contains a brief statement concerning these three points.

At this time it seems desirable to bring the history up to date and especially to list all past officers and all fellows as a matter of record. In this statement I have brought together material from the reports of the annual meetings and condensed it for reference.

The report contains the names of all past presidents, past vice presidents, secretaries, treasurers, editors, and fellows in addition to information relative to the growth of the Society and of the JOURNAL.

PAST PRESIDENTS

1907–08	M. A. Carlton	1925	C. W. Warburton
1909	G. N. Coffey	1926	C. G. Williams
1910	A. M. TenEyck	1927	W. L. Burlison
1911	H. J. Wheeler	1928	A. G. McCall
1912	R. W. Thatcher	1929	M. J. Funchess
1913	L. A. Clinton	1930	W. P. Kelly
1914	C. V. Piper	1931	W. W. Burr
1915	C. E. Thorne	1932	P. E. Brown
1916	C. R. Ball	1933	M. A. McCall
1917	W. M. Jardine	1934	R. I. Throckmorton
1918	T. Lyttleton Lyon	1935	H. K. Hayes
1919	J. G. Lipman	1936	R. M. Salter
1920	F. S. Harris	1937	F. D. Richey
1921	Charles A. Mooers	1938	Emil Truog
1922	L. E. Call	1939	R. J. Garber
1923	S. B. Haskell	1940	F. J. Alway
1924	M. F. Miller	1941	L. E. Kirk

PAST VICE PRESIDENTS

	First	Second
1907-08	C. P. Bull	J. F. Duggar
1909	J. F. Duggar	J. G. Lipman
1910	A. R. Whitson	C. A. Zavitz
1911	C. A. Zavitz	R. W. Thatcher
1912	C. A. Mooers	L. A. Clinton
1913	L. H. Smith	Lyman Carrier
1914	C. E. Thorne	E. G. Montgomery
1915	L. J. Briggs	Alfred Atkinson
1916	Alfred Atkinson	A. N. Hume
1917	J. G. Lipman	J. A. Foord
1918	A. G. McCall	C. B. Lipman
1919	F. S. Harris	A. B. Conner
1920	C. G. Williams	H. W. Barre
1921	S. B. Haskell	C. B. Lipman
1922	D. E. Stephens	A. B. Conner
1923	M. F. Miller	Emil Truog

	First	Second	Third	Fourth
1924	W. L. Burlison	Clyde McKee	S. B. Haskell	C. A. Mooers
1925	A. G. McCall	W. L. Burlison	M. J. Funchess	E. F. Gaines
1926	W. L. Burlison	M. J. Funchess	E. F. Gaines	A. G. McCall
1927	M. J. Funchess	E. F. Gaines	A. G. McCall	W. W. Burr

	First	Second
1928	E. F. Gaines	M. J. Funchess
1929	Clyde McKee	W. W. Burr
1930	W. W. Burr	A. B. Beaumont
1931	A. B. Beaumont	S. A. Waksman
1932	S. A. Waksman	Geo. Stewart

	Third	Fourth
1928	W. W. Burr	A. B. Beaumont
1929	A. B. Beaumont	A. S. Waksman
1930	S. A. Waksman	Geo. Stewart
1931	Geo. Stewart	R. I. Throckmorton
1932	R. I. Throckmorton	M. A. McCall

	Vice President	Chairman Crops Section	Chairman Soils Section
1933*	R. I. Throckmorton	M. T. Jenkins	Richard Bradfield
1934	H. K. Hays	H. L. Westover	C. E. Shaw
1935	R. M. Salter	R. D. Lewis	C. E. Millar
1936	F. D. Richey	H. B. Sprague	W. A. Albrecht
1937	Emil Truog	O. A. Aamodt	Richard Bradfield
1938	R. J. Garber	Ide P. Trotter	A. M. O'Neal
1939	F. J. Alway	F. D. Keim	W. A. Albrecht
1940	L. E. Kirk	S. C. Salmon	W. H. Pierre
1941	Richard Bradfield	C. J. Willard	C. E. Kellogg

SECRETARIES AND TREASURERS

	Secretaries	Treasurers
1907–08	T. Lyttleton Lyon	E. G. Montgomery
1909	T. Lyttleton Lyon	E. G. Montgomery
1910	Carleton R. Ball	Louie H. Smith
1911	Carleton R. Ball	Lyman Carrier
1912	Carleton R. Ball	A. G. McCall
1913	Carleton R. Ball	George Roberts
1914	Carleton R. Ball	George Roberts
1915	C. W. Warburton	George Roberts
1916	C. W. Warburton	George Roberts
1917	C. W. Warburton	George Roberts

SECRETARY-TREASURER COMBINED

1918	P. V. Cardon succeeded by Lyman Carrier March 11, 1918
1919	Lyman Carrier
1920	Lyman Carrier
1921–32	Percy E. Brown
1932	F. B. Smith
1933–38	Percy E. Brown
1938	F. B. Smith
1939	G. G. Polhman to present time

From 1907 to 1917, inclusive, the positions of Secretary and Treasurer were separate and were held as follows: T. Lyttleton Lyon was secretary during 1907, 1908, and 1909. He was succeeded by Carleton R. Ball, who served until 1915 when he was succeeded by C. W. Warburton, who continued in office for three years. E. G. Montgomery was treasurer during 1907, 1908, and 1909. He was succeeded by Louie H. Smith who served for one year. Lyman Carrier was treasurer in 1911 and A. G. McCall in 1912. A. G. McCall was succeeded by George Roberts who served as treasurer from 1913 to 1917 inclusive.

At the suggestion of George Roberts, the offices of Secretary and Treasurer were combined in the fall of 1917. P. V. Cardon was elected to fill the office but resigned in the spring of 1918, and Lyman Carrier was appointed on March 11

*With the organization of the Society into a Crops Section and a Soils Section for convenience in preparing programs for the annual meetings and the adoption of the new constitution at the 1932 meeting, the system of having four vice presidents was discontinued effective January 1, 1933. Since that time the offices have consisted of the President, Vice President, the Chairman of each of the Crops and Soils Sections, the Secretary, and the Editor.

of that year to succeed him. Lyman Carrier continued to serve as Secretary-Treasurer for two more years. In the fall of 1920, Percy E. Brown was elected to the office of Secretary-Treasurer, and continued in this office until the time of his death July 7, 1937, with the exception of 1932 when he was President of the Society and the duties of Secretary-Treasurer were carried by F. B. Smith. Following the death of Doctor Brown, the Executive Committee appointed F. B. Smith as Secretary-Treasurer, and he continued in this capacity until his resignation in the fall of 1938. G. G. Pohlman has served the Society as Secretary-Treasurer since 1938.

EDITORS

The first six volumes of the JOURNAL were edited by C. R. Ball, who was elected Secretary of the Society in 1909 at which time it was voted that the PROCEEDINGS of the Society be published. The publication of the PROCEEDINGS continued until 1913 when provision was made for the publication of the JOURNAL of the American Society of Agronomy. Doctor Ball continued to edit the JOURNAL through 1914. C. W. Warburton succeeded Doctor Ball as Secretary-Editor, beginning January 1, 1915. Doctor Warburton continued as Editor until 1922, but he was relieved of the duties of Secretary beginning January 1, 1918.

The joint responsibility apparently was a heavy load as was voiced by Secretary-Editor Warburton at the 1916 meeting of the Society in these words, "That dual official urges a separation of the two offices, in order to afford at least a partial relief from present conditions." The relief was not provided at once, but did come one year later when the position of Secretary was combined with that of Treasurer.

Beginning with volume 14, 1922, R. W. Thatcher became Editor of the JOURNAL. In 1923, J. D. Luckett became Assistant Editor and Advertising Manager. These men worked together until the fall of 1927 when Doctor Thatcher resigned and Mr. Luckett became Editor. Since January 1928, Mr. Luckett has had the full responsibility of editing the JOURNAL.

Thus, the editors of the JOURNAL may be listed as follows:

C. R. Ball	1909–14
C. W. Warburton	1915–21
R. W. Thatcher	1922–27
J. D. Luckett	1928 to present time

THE JOURNAL

The growth of the JOURNAL has been phenomenal but has been in line with its value and recognition. Volumes 1 to 4, inclusive, contain only the proceedings of the annual meetings.

In 1913 the JOURNAL was issued quarterly and in 1914 six numbers were published. Six numbers were issued in 1915 and in 1916. Nine numbers were published in 1917, 1918, 1919, 1920, 1921, and 1922. In 1922, however, because of the number of papers presented to the Editor, it became necessary to provide for a larger JOURNAL and beginning with volume 15, 1923, and continuing to the present time each volume has contained 12 numbers.

With the increase in the size of the JOURNAL, financial difficulties appeared. The annual dues were $2.00 until 1918. At the annual meeting in 1917 the dues were increased to $2.50, and it was in 1917 that nine numbers of the JOURNAL were first issued. When the JOURNAL was increased to 12 numbers in 1923, the annual dues were increased to $5.00.

MEMBERSHIP OF THE SOCIETY BY YEARS

1908—121	1919—473	1930— 943
1909—129	1920—436	1931— 963
1910—176	1921—592	1932— 949
1911—236	1922—643	1933— 904
1912—295	1923—561	1934— 868
1913—349	1924—577	1935— 901
1914—397	1925—646	1936—1,166
1915—471	1926—700	1937—1,213
1916—586	1927—767	1938—1,230
1917—652	1928—823	1939—1,205
1918—509	1929—906	1940—1,176

World conditions are reflected in the fluctuations in membership. There was a steady increase in the number of members of the Society from the time of its organization until World War I when a decline took place. The membership increased again until the depression of the early twenties when there was a slight reduction. Beginning with 1925 the membership increased rather rapidly until the start of the depression of the thirties when there was a slight decline. The increase of the activities of the U. S. Dept. of Agriculture accompanied by an increase in personnel was perhaps primarily responsible for the rapid increase in the membership from 1934 to 1938. The decline in membership since 1938 may be a reflection of World War II. The mailing list of the JOURNAL far exceeds the number of members because of personal subscriptions, library subscriptions, and others. The October 1941 number of the JOURNAL, for example, was mailed to 1,867 members and subscribers.

FELLOWS OF AMERICAN SOCIETY OF AGRONOMY

The first election of members of the Society to Fellows was at the 1925 meeting in Chicago. Fellows have been elected each year since that time.

1925 Charles E. Thorne, C. R. Ball, S. B. Haskell, R. W. Thatcher, J. G. Lipman, M. F. Miller, T. L. Lyon, C. V. Piper, C. W. Warburton, P. E. Brown, L. E. Call, C. A. Zavitz

1926 B. L. Hartwell, C. G. Williams, H. H. Love, Emil Truog, C. A. Mooers

1927 F. J. Alway, T. A. Kiesselbach, A. G. McCall, R. A. Oakley, H. K. Hayes

1928 C. F. Marbut, A. J. Pieters, George Roberts, Oswald Schreiner, A. F. Wiancko

1929 W. L. Slate, H. L. Shantz, E. F. Gaines

1930 F. S. Harris, J. A. Bizzell, W. P. Kelley

1931 W. W. Burr, F. D. Gardner, M. A. McCall, C. F. Shaw, W. H. Stevenson

1932	A. B. Beaumont Andrew Boss M. J. Funchess	S. C. Salmon F. T. Shutt
1933	R. J. Garber R. I. Throckmorton	A. R. Whitson
1934	J. H. Parker F. D. Richey	R. M. Salter
1935	A. C. Arny Richard Bradfield	C. E. Millar
1936	W. L. Burlison L. J. Stadler	S. A. Waksman
1937	O. S. Aamodt W. A. Albrecht F. E. Bear H. O. Buckman G. W. Conrey	H. D. Hughes F. D. Keim R. D. Lewis J. D. Luckett H. L. Westover
1938	W. H. Pierre Ide P. Trotter	C. J. Willard
1939	L. D. Baver M. T. Jenkins	A. L. Patrick
1940	L. F. Graber P. C. Mangelsdorf	F. W. Parker H. R. Smalley

HONORARY MEMBERS

The Society apparently has been reluctant to elect men to honorary membership. Only one man has been elected to such membership. At the annual meeting in Chicago, November 16, 1925, Dr. W. M. Jardine, then Secretary of Agriculture, was elected an honorary member on the recommendation of the Executive Committee.

R. I. THROCKMORTON, *Historian.*

AGRONOMIC AFFAIRS

MINUTES OF THE CROPS SECTION OF THE AMERICAN SOCIETY OF AGRONOMY

THE business meeting of the Crops Section was held on the afternoon of Wednesday, November 12, before the general session of the Section.

Dr. B. B. Bayles and Dr. W. W. Worzella reported that a resolution had been passed at a meeting of the eastern soft wheat breeders held at Lafayette, Indiana, on June 20, 1941, recommending that the Crops Section appoint a committee to consider uniform designations for genes studied in wheat. No great amount of literature has accumulated, but designations are now somewhat chaotic. It was felt such a committee could forestall more serious complications arising from lack of uniformity, and use of symbols for more than one character. The Section voted that the Chairman appoint such a committee.

The Section instructed the Program Committee to continue to prepare abstracts of the papers to be given at the annual meeting, for distribution as was done this year, or as may be feasible.

The Nominating Committee, consisting of Dr. Ide P. Trotter, Dr. Roy G. Wiggans, and Mr. Earl Jones, nominated Dr. K. S. Quisenberry as Chairman of the Crops Section for 1942 and Dr. L. F. Graber and Mr. J. S. Owens as the two other members of the Program Committee. They were unanimously elected.

C. A. LAMB, *Secretary*

OFFICERS OF THE AMERICAN SOCIETY OF AGRONOMY FOR 1942

President, RICHARD BRADFIELD, Cornell University.
Vice President, F. D. KEIM, University of Nebraska.
Chairman of the Crops Section, K. S. QUISENBERRY, U. S. Dept. of Agriculture.
Chairman of the Soils Section, H. J. HARPER, Oklahoma A. & M. College.
Secretary-Treasurer, G. G. POHLMAN, University of West Virginia.
Editor, J. D. LUCKETT, New York State Experiment Station.
Representatives on Council of A. A. A. S., H. J. HARPER, Oklahoma A. & M. College, and IDE P. TROTTER, Texas A. & M. College.
Members of the Executive Committee, L. E. KIRK, University of Saskatchewan, and F. J. ALWAY, University of Minnesota.

OFFICERS OF THE SOIL SCIENCE SOCIETY OF AMERICA FOR 1942

President, H. J. HARPER, Oklahoma A. & M. College.
Past President, C. E. KELLOGG, U. S. Dept. of Agriculture.
Secretary, F. E. BEAR, Rutgers University.
Treasurer, G. G. POHLMAN, University of West Virginia.
Editor, J. D. LUCKETT, New York State Experiment Station.

SECTION I—SOIL PHYSICS

Chairman, J. C. RUSSELL, University of Nebraska.
Past Chairman, WILLARD GARDNER, Utah State College.
Secretary, S. B. HENDRICKS, U. S. Dept. of Agriculture.

SECTION II—SOIL CHEMISTRY

Chairman, H. D. CHAPMAN, University of California.
Past Chairman, C. E. MARSHALL, University of Missouri.
Secretary, HANS JENNY, University of California.

SECTION III—SOIL MICROBIOLOGY

Chairman, R. G. NORMAN, Iowa State College.
Past Chairman, O. H. SEARS, University of Illinois.
Secretary, HERBERT REUSZER, Alabama Polytechnic Institute.

SECTION IV—SOIL FERTILITY

Chairman, R. L. COOK, Michigan State College.

Past Chairman, J. A. NAFTEL, Alabama Polytechnic Institute.
Secretary, B. A. BROWN, University of Connecticut.

SECTION V—SOIL GENESIS, MORPHOLOGY, AND CARTOGRAPHY

Chairman, J. W. MOON, Tennessee Valley Authority.
Past Chairman, H. H. KRUSEKOPF, University of Missouri.
Secretary, EARL STORIE, University of California.

SECTION VI—SOIL TECHNOLOGY

Chairman, H. C. KNOBLAUCH, U. S. Dept. of Agriculture.
Past Chairman, G. D. SCARSETH, Purdue University.
Secretary, J. S. OWEN, University of Connecticut.

EXHIBITS AT THE ANNUAL MEETING

A NUMBER of novel and interesting exhibits on subjects pertaining to both crops and soils contributed materially to the value of the meetings of the American Society of Agronomy and the Soil Science Society in Washington November 12 to 14. Dr. Glenn W. Burton, Associate Geneticist of the Division of Forage Crops and Diseases, U. S. Dept. of Agriculture, solicited and arranged the crops exhibits, assisted by Dr. E. A. Hollowell, Dr. John Martin, and M. M. Hoover. Dr. C. C. Nikiforoff, Soil Scientist, Division of Soil Survey, U. S. Dept. of Agriculture, supervised the arrangement of the soils exhibits.

The crops exhibits included the following units: Forage grass diseases, H. Johnson and C. L. Lefebore, Washington, D. C.; interspecific and intergeneric crosses, W. J. Sando, Washington, D. C.; Paspalum species hybridization—a grass-breeding method, G. W. Burton, Tifton, Ga.; raising to maturity of F_1 hybrids of the cross *Melilotus alba*$\times$*M. dentata* by grafting, W. K. Smith, Madison, Wis.; beachgrass transplanter, Soil Conservation Service; native grass seed collecting and processing, Soil Conservation Service; domestication of native grasses for conservation, Soil Conservation Service; machine for Stipa seed processing, D. C. Sumner and R. M. Love, Davis, Calif.; lawnmower equipment for harvesting pasture plots, G. O. Mott, Lafayette, Ind.; Bates laboratory aspirator for air separation of threshed grain samples, U. S. Dept. of Agriculture; barley pearling machine to test wheat hardness, U. S. Dept. of Agriculture; rubber tube head thresher, G. A. Wiebe, Washington, D. C.; rubbing-board head thresher, Merritt Pope, Washington, D. C.; hot water emasculation of rice, N. E. Jodon, Crowley, La.; special leg desk for taking notes, W. J. Sando, Washington, D. C.; potted plant support, J. W. Taylor and F. A. Coffman, Washington, D. C.; metal nursery label, H. M. Beachell, Beaumont, Texas; nursery equipment developed at Washington State College, O. A. Vogel, Pullman, Wash.; nursery harvester and seed cleaner, V. C. Hubbard, Woodward, Okla.; testing for lodging resistance, I. M. Atkins, Denton, Texas; wheat shattering machine, P. B. Dunkle, Denton, Texas; nursery planter, M. G. Weiss, Ames, Iowa; alfalfa plot technic, Ralph Weihing, Fort Collins, Colo.; moisture tester for grains and forage, R. Q. Parks,

Wooster, Ohio; scale-leveling platform, E. M. Brown, Columbia, Mo.; integrating light recorder, V. G. Sprague, State College, Pa.; self-cleaning all-metal nursery thresher for small samples, E. G. Heyne, Manhattan, Kan.; and grass sod sampler, E. M. Brown, Columbia, Mo.

The soils exhibits included a soil map of the United States accompanied by large monolith samples of the zonal soils, collections of samples, charts, and photographs of soil structure and soil texture, and charts and tables illustrating the principles of soil productivity rating arranged by the Division of Soil Survey, U. S. Dept of Agriculture; sampling kit and collection of soil samples from Indiana taken by the original Bushnell method, T. M. Bushnell, Lafayette, Ind.; monolith samples, photographs, and charts illustrating forest humus layer types of the Northeast, John G. Cady, Ithaca, N. Y.; color standards with a collection of soil colors, Mrs. D. Nickerson and A. M. O'Neal, Washington, D. C.; and a collection of kodachrome slides of soil profiles and related subjects arranged by S. S. Obenshain, Blacksburg, Va., for the committee on the exchange of soil profiles and pictures of Section V of the Soil Science Society.

The National Fertilizer Association also had an attractive display built around their new book on "Hunger Signs in Crops" which was sponsored by the American Society of Agronomy.

NEWS ITEMS

Dr. Robert M. Salter, formerly Director of the North Carolina Agricultural Experiment Station, was appointed Chief of the Division of Soil and Fertilizer Investigations of the U. S. Dept. of Agriculture and entered upon his new duties October 1.

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Dr. L. D. Baver, formerly head of the Department of Agronomy at the North Carolina Agricultural Experiment Station, has been appointed Director of the Experiment Station to fill the vacancy occasioned by Doctor Salter's resignation.

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Dr. Ralph W. Cummings of the Department of Agronomy at Cornell University has been appointed head of the Department of Agronomy at the North Carolina Agricultural Experiment Station and will enter upon his new duties on February 1.

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North Carolina State College announces the Pieters Memorial Graduate Scholarship to commemorate the life and work of Dr. Adrian J. Pieters, long a leader in agriculture and a pioneer in the development of lespedeza. This scholarship has been initiated by his wife, Mary Burr Pieters, to carry forward through graduate study his work with lespedeza and other acid-tolerant legumes. The first award has been to E. Lamar Whiteley, graduate of Texas A. & M. College.

DUKE UNIVERSITY SCHOOL OF FORESTRY Bulletin No. 5. entitled "Soil Changes Associated with Loblolly Pine Succession on Abandoned Agricultural Land of the Piedmont Plateau", by Theodore S. Coile, is now obtainable from the University of Durham, N. C., for 75 cents a copy. The material in the bulletin is condensed from a thesis submitted by the author to the Graduate School of Yale University for the degree of doctor of philosophy.

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THE NORTHWEST CROP IMPROVEMENT ASSOCIATION of Minneapolis, Minn., has issued the second edition of its "Dictionary of Spring Wheat Varieties" in which varietal recommendations are made for different areas of the spring wheat belt based upon tests carried on at the Minnesota, North Dakota, Montana, and South Dakota agricultural experiment stations. The book may be purchased from the Association for 50 cents a copy.

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THE NATIONAL FERTILIZER ASSOCIATION has published in mimeographed form the proceedings of the National Joint Committee on Fertilizer Application and the minutes of the meeting of the Committee on Fertilizers of the American Society of Agronomy presented before the meetings of these two groups in Washington, D. C., November 10 and 11. These publications may be obtained by writing to H. R. Smalley of the National Fertilizer Association, Investment Building, Washington, D. C.

ERRATUM

IN the article by Paul M. Harmer and Erwin J. Benne on "Effects of Applying Common Salt to a Muck Soil on the Yield, Composition, and Quality of Certain Vegetable Crops and on the Composition of the Soil Producing Them", which appears in the November number of the JOURNAL, an error occurs in the alinement of the data in Table 6, page 965, under the heading "Kohlrabi, 1938". According to a footnote to the table, all of the plants on plot No. 12 of this series died during the growing season, hence no data on composition should appear opposite plot No. 12. In other words, all of the figures under the heading "Kohlrabi, 1938" should be raised a line, leaving the bottom line blank.

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